opy for the Elected Office (EO/US)

PCT/EP98/02170

F ENT COOPERATION TREA

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

To:

SCHOPPE, Fritz
Schoppe Zimmermann & Stöckeler
Postfach 71 08 67
D-81458 München
ALLEMAGNE

Date of mailing (day/month/year)
18 August 1999 (18.08.99)

Applicant's or agent's file reference
FH980403PCT

IMPORTANT NOTIFICATION

International application No.
PCT/EP98/02170

International filing date (day/month/year)
14 April 1998 (14.04.98)

1. The following indications appeared on record concerning:

[ ] the applicant [ ] the inventor [X] the agent [ ] the common representative

Name and Address
SCHOPPE, Fritz
Schoppe & Zimmermann
Postfach 71 08 67
D-81458 München
Germany

State of Nationality:
State of Residence:
Telephone No.: 089/790 44 50
Facsimile No.: 089/790 22 15
Teleprinter No.:

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

[ ] the person [ ] the name [X] the address [ ] the nationality [ ] the residence

Name and Address
SCHOPPE, Fritz
Schoppe Zimmermann & Stöckeler
Postfach 71 08 67
D-81458 München
Germany

State of Nationality:
State of Residence:
Telephone No.: 089/790 44 50
Facsimile No.: 089/790 22 15
Teleprinter No.:

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

[X] the receiving Office
[ ] the International Searching Authority
[X] the International Preliminary Examining Authority
[ ] the designated Offices concerned
[X] the elected Offices concerned
[ ] other:

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland
Facsimile No.: (41-22) 740.14.35

Authorized officer
Maria Victoria CORTIELLO
Telephone No.: (41-22) 338.83.38

002794686

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

From the INTERNATIONAL BUREAU

To:

Assistant Commissioner for Patents
United States Patent and Trademark Office
Box PCT
Washington, D.C.20231
ÉTATS-UNIS D'AMÉRIQUE

in its capacity as elected Office

Date of mailing: 21 October 1999 (21.10.99)	
International application No.: PCT/EP98/02170	Applicant's or agent's file reference: FH980403PCT
International filing date: 14 April 1998 (14.04.98)	Priority date:
Applicant: EBERLEIN, Ernst et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International preliminary Examining Authority on:

22 July 1999 (22.07.99)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No.: (41-22) 740.14.35

Authorized officer:

J. Zahra

Telephone No.: (41-22) 338.83.38

PCT

REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

For receiving Office use only

International Application No.

International Filing Date

Name of receiving Office and "PCT International Application"

Applicant's or agent's file reference *(if desired) (12 characters maximum)* FH980403PCT

Box No. I TITLE OF INVENTION

METHOD AND APPARATUS FOR COARSE FREQUENCY SYNCHRONIZATION

Box No. II APPLICANT

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

Fraunhofer-Gesellschaft zur Förderung
der angewandten Forschung e. V.
Leonrodstraße 54
D-80636 München
DE

☐ This person is also inventor.

Telephone No.

Facsimile No.

Teleprinter No.

State *(i.e. country)* of nationality: DE

State *(i.e. country)* of residence: DE

This person is applicant for the purposes of: ☐ all designated States ☒ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

EBERLEIN, Ernst
Waldstraße 28 b
D-91091 Großenseebach
DE

This person is:

☐ applicant only

☒ applicant and inventor

☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality: DE

State *(i.e. country)* of residence: DE

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

☒ Further applicants and/or (further) inventors are indicated on a continuation sheet.

Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: ☒ agent ☐ common representative

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

SCHOPPE, Fritz
Schoppe & Zimmermann
Postfach 71 08 67
D-81458 München
DE

Telephone No. 0 89/7 90 445-0

Facsimile No. 0 89/7 90 22 15

Teleprinter No. —

☐ Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Continuation of Box No. III FURTHER APPLICANTS AND/OR (FURTHER) INVENTORS

If none of the following sub-boxes is used, this sheet is not to be included in the request.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

BADRI, Sabah
Sebaldusstraße 8
D-91058 Erlangen
DE

This person is:
- [ ] applicant only
- [X] applicant and inventor
- [ ] inventor only *(If this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality: MA

State *(i.e. country)* of residence: DE

This person is applicant for the purposes of:
- [ ] all designated States
- [ ] all designated States except the United States of America
- [X] the United States of America only
- [ ] the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

LIPP, Stefan
Steinweg 9 a
D-91058 Erlangen
DE

This person is:
- [ ] applicant only
- [X] applicant and inventor
- [ ] inventor only *(If this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality: DE

State *(i.e. country)* of residence: DE

This person is applicant for the purposes of:
- [ ] all designated States
- [ ] all designated States except the United States of America
- [X] the United States of America only
- [ ] the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

BUCHHOLZ, STEPHAN
Spinnereistraße 20
D-91052 Erlangen
DE

This person is:
- [ ] applicant only
- [X] applicant and inventor
- [ ] inventor only *(If this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality: DE

State *(i.e. country)* of residence: DE

This person is applicant for the purposes of:
- [ ] all designated States
- [ ] all designated States except the United States of America
- [X] the United States of America only
- [ ] the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

HEUBERGER, Albert
Hausäckerweg 18
D-91056 Erlangen
DE

This person is:
- [ ] applicant only
- [X] applicant and inventor
- [ ] inventor only *(If this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality: DE

State *(i.e. country)* of residence: DE

This person is applicant for the purposes of:
- [ ] all designated States
- [ ] all designated States except the United States of America
- [X] the United States of America only
- [ ] the States indicated in the Supplemental Box

[X] Further applicants and/or (further) inventors are indicated on another continuation sheet.

Continuation of Box No. III FURTHER APPLICANTS AND/OR (FURTHER) INVENTORS

If none of the following sub-boxes is used, this sheet is not to be included in the request.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

GERHÄUSER, Heinz
Saugendorf 17
D-91344 Waischenfeld
DE

This person is:
- ☐ applicant only
- ☒ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality: DE

State *(i.e. country)* of residence: DE

This person is applicant for the purposes of:
- ☐ all designated States
- ☐ all designated States except the United States of America
- ☒ the United States of America only
- ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

This person is:
- ☐ applicant only
- ☐ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality:

State *(i.e. country)* of residence:

This person is applicant for the purposes of:
- ☐ all designated States
- ☐ all designated States except the United States of America
- ☐ the United States of America only
- ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

This person is:
- ☐ applicant only
- ☐ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality:

State *(i.e. country)* of residence:

This person is applicant for the purposes of:
- ☐ all designated States
- ☐ all designated States except the United States of America
- ☐ the United States of America only
- ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

This person is:
- ☐ applicant only
- ☐ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality:

State *(i.e. country)* of residence:

This person is applicant for the purposes of:
- ☐ all designated States
- ☐ all designated States except the United States of America
- ☐ the United States of America only
- ☐ the States indicated in the Supplemental Box

☐ Further applicants and/or (further) inventors are indicated on another continuation sheet.

Box No.V DESIGNATION OF STATES

The following designations are hereby made under Rule 4.9(a) *(mark the applicable check-boxes; at least one must be marked)*:

Regional Patent

- ☒ AP **ARIPO Patent:** KE Kenya, LS Lesotho, MW Malawi, SD Sudan, SZ Swaziland, UG Uganda, and any other State which is a Contracting State of the Harare Protocol and of the PCT
- ☒ EA **Eurasian Patent:** AZ Azerbaijan, BY Belarus, KZ Kazakstan, RU Russian Federation, TJ Tajikistan, TM Turkmenistan, and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT
- ☒ EP **European Patent:** AT Austria, BE Belgium, CH and LI Switzerland and Liechtenstein, DE Germany, DK Denmark, ES Spain, FR France, GB United Kingdom, GR Greece, IE Ireland, IT Italy, LU Luxembourg, MC Monaco, NL Netherlands, PT Portugal, SE Sweden, and any other State which is a Contracting State of the European Patent Convention and of the PCT
- ☒ OA **OAPI Patent:** BF Burkina Faso, BJ Benin, CF Central African Republic, CG Congo, CI Côte d'Ivoire, CM Cameroon, GA Gabon, GN Guinea, ML Mali, MR Mauritania, NE Niger, SN Senegal, TD Chad, TG Togo, and any other State which is a member State of OAPI and a Contracting State of the PCT *(if other kind of protection or treatment desired, specify on dotted line)* .....

National Patent *(if other kind of protection or treatment desired, specify on dotted line)*:

- ☒ AL Albania
- ☒ AM Armenia
- ☒ AT Austria
- ☒ AU Australia
- ☒ AZ Azerbaijan
- ☒ BB Barbados
- ☒ BG Bulgaria
- ☒ BR Brazil
- ☒ BY Belarus
- ☒ CA Canada
- ☒ CH and LI Switzerland and Liechtenstein
- ☒ CN China
- ☒ CZ Czech Republic
- ☒ DE Germany
- ☒ DK Denmark
- ☒ EE Estonia
- ☒ ES Spain
- ☒ FI Finland
- ☒ GB United Kingdom
- ☒ GE Georgia
- ☒ HU Hungary
- ☒ IS Iceland
- ☒ JP Japan
- ☒ KE Kenya
- ☒ KG Kyrgyzstan
- ☒ KP Democratic People's Republic of Korea
- ☒ KR Republic of Korea
- ☒ KZ Kazakstan
- ☒ LK Sri Lanka
- ☒ LR Liberia
- ☒ LS Lesotho
- ☒ LT Lithuania
- ☒ LU Luxembourg
- ☒ LV Latvia
- ☒ MD Republic of Moldova
- ☒ MG Madagascar
- ☒ MK The former Yugoslav Republic of Macedonia
- ☒ MN Mongolia
- ☒ MW Malawi
- ☒ MX Mexico
- ☒ NO Norway
- ☒ NZ New Zealand
- ☒ PL Poland
- ☒ PT Portugal
- ☒ RO Romania
- ☒ RU Russian Federation
- ☒ SD Sudan
- ☒ SE Sweden
- ☒ SG Singapore
- ☒ SI Slovenia
- ☒ SK Slovakia
- ☒ TJ Tajikistan
- ☒ TM Turkmenistan
- ☒ TR Turkey
- ☒ TT Trinidad and Tobago
- ☒ UA Ukraine
- ☒ UG Uganda
- ☒ US United States of America
- ☒ UZ Uzbekistan
- ☒ VN Viet Nam

Check-boxes reserved for designating States (for the purposes of a national patent) which have become party to the PCT after issuance of this sheet:

- ☒ Cuba (CU)
- ☒ Ghana (GH)
- ☒ Israel (IL)
- ☒ Saint Lucia (LC)
- ☒ Sierra Leone (SL)
- ☒ Bosnien-Herzegowina (BA
- ☒ Jugoslavia (YU)
- ☒ Zimbabwe (ZW)

In addition to the designations made above, the applicant also makes under Rule 4.9(b) all designations which would be permitted under the PCT except the designation(s) of _____.

The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit. *(Confirmation of a designation consists of the filing of a notice specifying that designation and the payment of the designation and confirmation fees. Confirmation must reach the receiving Office within the 15-month time limit.)*

Box No. VI PRIORITY CLAIM Further priority claims are in[illegible] in the Supplemental Box ☐

The priority of the following earlier application(s) is hereby claimed:

Country *(in which, or for which, the application was filed)*	Filing Date *(day/month/year)*	Application No.	Office of filing *(only for regional or international application)*
item (1)			
item (2)			
item (3)			

Mark the following check-box if the certified copy of the earlier application is to be issued by the Office which for the purposes of the present international application is the receiving Office (a fee may be required):

☐ The receiving Office is hereby requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) identified above as item(s) :

Box No. VII INTERNATIONAL SEARCHING AUTHORITY

Choice of International Searching Authority (ISA) *(If two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used):* ISA /

Earlier search *Fill in where a search (international, international-type or other) by the International Searching Authority has already been carried out or requested and the Authority is now requested to base the international search, to the extent possible, on the results of that earlier search. Identify such search or request either by reference to the relevant application (or the translation thereof) or by reference to the search request:*

Country (or regional Office): Date *(day/month/year)*: Number:

Box No. VIII CHECK LIST

This international application contains the following number of sheets:

1. request	:	5	sheets
2. description	:	18	sheets
3. claims	:	8	sheets
4. abstract	:	1	sheets
5. drawings	:	5	sheets
Total	:	37	sheets

This international application is accompanied by the item(s) marked below:

1. ☐ separate signed power of attorney
2. ☒ copy of general power of attorney
3. ☐ statement explaining lack of signature
4. ☐ priority document(s) *identified in Box No. VI as item(s):*
5. ☒ fee calculation sheet
6. ☐ separate indications concerning deposited microorganisms
7. ☐ nucleotide and/or amino acid sequence listing (diskette)
8. ☐ other *(specify)*:

Figure No. Fig. 2 of the drawings (if any) should accompany the abstract when it is published.

Box No. IX SIGNATURE OF APPLICANT OR AGENT

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request).

Munich, April 14, 1998 SCHOPPE, Fritz

For receiving Office use only

1. Date of actual receipt of the purported international application:
2. Drawings: ☐ received: ☐ not received:
3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application:
4. Date of timely receipt of the required corrections under PCT Article 11(2):
5. International Searching Authority specified by the applicant: ISA /
6. ☐ Transmittal of search copy delayed until search fee is paid

For International Bureau use only

Date of receipt of the record copy by the International Bureau:

This sheet is not part of and does not count as a sheet of the international application.

PCT

FEE CALCULATION SHEET

Annex to the Request

For receiving Office use only

International application No.

Date stamp of the receiving Office

Applicant's or agent's file reference: FH980403PCT

Applicant: Fraunhofer-Gesellschaft ... et al

CALCULATION OF PRESCRIBED FEES

1. TRANSMITTAL FEE . . . . . 200,00 T

2. SEARCH FEE . . . . . 2 200,00 S

International search to be carried out by _____

(If two or more International Searching Authorities are competent in relation to the international application, indicate the name of the Authority which is chosen to carry out the international search.)

3. INTERNATIONAL FEE

Basic Fee

The international application contains 37 sheets.

first 30 sheets . . . . . 800,00 b_1

7 (remaining sheets) x 19,00 (additional amount) = 133,00 b_2

Add amounts entered at b_1 and b_2 and enter total at B . . . . 933,00 B

Designation Fees

The international application contains 72 designations.

11 (number of designation fees payable *(maximum 11)*) x 184,00 (amount of designation fee) = 2 024,00 D

Add amounts entered at B and D and enter total at I . . . . . 2 957,00 I

(Applicants from certain States are entitled to a reduction of 75% of the international fee. Where the applicant is (or all applicants are) so entitled, the total to be entered at I is 25% of the sum of the amounts entered at B and D.)

4. FEE FOR PRIORITY DOCUMENT . . . . . P

5. TOTAL FEES PAYABLE

Add amounts entered at T, S, I and P, and enter total in the TOTAL box . . 5 357,00 TOTAL

☐ The designation fees are not paid at this time.

MODE OF PAYMENT

☒ authorization to charge deposit account (see below)	☐ bank draft	☐ coupons
☐ cheque	☐ cash	☐ other *(specify):*
☐ postal money order	☐ revenue stamps	

DEPOSIT ACCOUNT AUTHORIZATION *(this mode of payment may not be available at all receiving Offices)*

The RO/ _____

☒ is hereby authorized to charge the total fees indicated above to my deposit account.

☒ is hereby authorized to charge any deficiency or credit any overpayment in the total fees indicated above to my deposit account.

☐ is hereby authorized to charge the fee for preparation and transmittal of the priority document to the International Bureau of WIPO to my deposit account.

2800 0601	April 14, 1998	SCHOPPE, Fritz
Deposit Account Number	Date *(day/month/year)*	Signature

SCHOPPE & ZIMMERMANN
PATENTANWÄLTE
European Patent Attorneys
European Trademark Attorneys

Fritz Schoppe, Dipl.-Ing.
Tankred Zimmermann, Dipl.-Ing.

Telefon/Telephone 089/790445-0
Telefax/Facsimile 089/790 22 15
Telefax/Facsimile 089/74996977
e-mail 101345, 3117 CompuServe

Schoppe & Zimmermann · Postfach 710867 · 81458 München

Fraunhofer-Gesellschaft
zur Förderung der
angewandten Forschung e. V.
Leonrodstraße 54
80636 München

METHOD AND APPARATUS FOR COARSE FREQUENCY SYNCHRONIZATION

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

SCHOPPE, Fritz
SCHOPPE, ZIMMERMANN & STÖCKELER
Postfach 71 08 67
81458 München
ALLEMAGNE

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL PRELIMINARY EXAMINATION REPORT
(PCT Rule 71.1)

Date of mailing *(day/month/year)*	18.08.00
Applicant's or agent's file reference FH980403PCT	**IMPORTANT NOTIFICATION**

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/EP98/02170	14/04/1998	14/04/1998

Applicant
FRAUNHOFER-GESELLSCHAFT...

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/	Authorized officer
European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Ahrens, R Tel.+49 89 2399-8136

Form PCT/IPEA/416 (July 1992)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
FH980403PCT		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/EP98/02170	14/04/1998	14/04/1998
International Patent Classification (IPC) or national classification and IPC H04L27/26		
Applicant FRAUNHOFER-GESELLSCHAFT...		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 5 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 23 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
22/07/1999	18.08.00
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Snell, T Telephone No. +49 89 2399 8802

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/EP98/02170

I. Basis of the report

1. This report has been drawn on the basis of (*substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.*):

Description, pages:

1,2,6-8,10,11,13, 15-17	as originally filed			
3-5,5a,9,12,14, 18	as received on	07/03/2000	with letter of	07/03/2000

Claims, No.:

1-22	as received on	07/03/2000	with letter of	07/03/2000

Drawings, sheets:

1/7-7/7	as received on	07/03/2000	with letter of	07/03/2000

2. The amendments have resulted in the cancellation of:

☐ the description, pages:
☐ the claims, Nos.:
☐ the drawings, sheets:

3. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

4. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims 1-22
	No:	Claims
Inventive step (IS)	Yes:	Claims 1-22
	No:	Claims
Industrial applicability (IA)	Yes:	Claims 1-22
	No:	Claims

2. Citations and explanations

see separate sheet

Cited document

D1: WO 98 00946 A (LELAND STANFORD JUNIOR UNIVERSITY) 8th January 1998

Re Item V

Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. The invention relates to a method (independent claims 1 and 3) of performing a coarse frequency synchronisation, for example in an OFDM environment, and a corresponding apparatus for carrying out the method (independent claims 12 and 14).

2. The closest prior art document D1 describes such a method, whereby two training symbols are placed into the OFDM frame, at least once every frame. The first training symbol is produced by modulating the even-numbered OFDM sub-carriers and suppressing the odd-numbered carriers, and the second training symbol is produced by modulating the odd-numbered OFDM sub-carriers and suppressing the even-numbered carriers. The modulation signal is a pseudo-noise signal. The synchronisation process is bound up with the decoding of the OFDM signal, as fast Fourier transforms of the two training signals are required.

3. According to the invention, a reference symbol placed in every frame comprises an amplitude modulated bit sequence. In order to perform the synchronisation an amplitude demodulation of the received and down-converted signal is performed, and correlated with a stored pattern. Thereby, in contrast to D1, synchronisation can be obtained before beginning with the decoding of the OFDM signal.

   As neither D1 nor the other documents cited in the international search report gives no hint to use amplitude demodulation prior to OFDM decoding to obtain coarse synchronisation, the subject-matter of claim 1 is novel and involves an inventive step (Articles 33(1)-(3) PCT).

4. Method claim 3 relates to a further embodiment using two identical symbols, but

still based on the same inventive concept. Apparatus claims 12 and 14 correspond to method claims 1 and 3. The subject-matter of claims 3, 12 and 14 is therefore also novel and involves an inventive step (Articles 33(1)-(3) PCT).

5. Claims 2, 4-11, 13 and 15-22 are all dependent on one of the independent claims 1, 3, 12 or 14 and thus also meet the requirements for novelty and inventive step (Articles 33(1)-(3) PCT).

WO 9800946 A relates to a system for a timing and frequency synchronization of OFDM signals. OFDM training symbols are used to obtain full synchronization in less than two data frames. The OFDM training symbols are placed into the OFDM signal, preferably at least once every frame. The first OFDM training symbol is produced by modulating the even-numbered OFDM sub-carriers whereas the odd-numbered OFDM sub-carriers are suppressed. Thus, the first OFDM training symbol is produced by modulating the even-numbered carriers of this symbol with a first predetermined pseudo noise sequence. This results in a time-domain OFDM symbol that has two identical halfs since each of the even-numbered sub-carrier frequencies repeats every half symbol interval. In case a carrier frequency offset is not greater than a sub-carrier bandwidth, the carrier frequency offset can be determined using the phase difference between the two halfs of the first OFDM training symbol. In case the carrier frequency offset can be greater than a sub-carrier bandwidth a second OFDM training symbol is used which is formed by using a second predetermined pseudo noise sequence to modulate the even-numbered frequencies of this symbol and by using a third predetermined pseudo noise sequence to modulate the odd-numbered carriers of this symbol. This second OFDM training symbol is used in order to determine an integer part of the carrier frequency offset. This integer part and a positive or negative fractional part determined from the first OFDM training symbol are used for performing the coarse frequency synchronization. In order to determine the integer part of the carrier frequency offset, fast Fourier transforms of the two training symbols are required.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide methods and apparatus for performing a coarse frequency synchronization even in the case of frequency offsets that correspond to a multiple of the subcarrier distance in a MCM signal.

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In accordance with a first aspect, the present invention provides a method of performing a coarse frequency synchronization compensating for a carrier frequency deviation from an oscillator frequency in a demodulation system capable of demodulating a signal having a frame structure comprising at least one useful symbol and a reference symbol, said reference symbol being an amplitude-modulated bit sequence, said method comprising the steps of:

receiving said signal;

down-converting said received signal;

performing an amplitude-demodulation of said down-converted signal in order to generate an envelope;

correlating said envelope with a predetermined reference pattern in order to determine said carrier frequency deviation; and

controlling said oscillator frequency based on said carrier frequency deviation.

In accordance with a second aspect, the present invention provides a method of performing a coarse frequency synchronization compensation for a carrier frequency deviation from an oscillator frequency in a demodulation system capable of demodulating a signal having a frame structure, said frame structure comprising at least one useful symbol and a reference symbol, said reference symbol being an amplitude-modulated bit sequence which comprises two identical sequences, said method comprising the steps of:

receiving said signal;

down-converting said received signal;

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performing an amplitude-demodulation of the down-converted signal in order to generate an envelope, said envelope having two portions which are based on said identical sequences;

correlating one of said portions of said envelope with another one of said portions in order to determine said carrier frequency deviation; and

controlling said oscillator frequency based on said carrier frequency deviation.

In accordance with a third aspect, the present invention provides an apparatus for performing a coarse frequency synchronization compensating for a carrier frequency deviation from an oscillator frequency, for a demodulation system capable of demodulating a signal having a frame structure, said frame structure comprising at least one useful symbol and a reference symbol, said reference symbol being an amplitude-modulated bit sequence, said apparatus comprising:

receiving means for receiving said signal;

a down-converter for down-converting said received signal;

an amplitude-demodulator for performing an amplitude-demodulation of said down-converted signal in order to generate an envelope;

a correlator for correlating said envelope with a predetermined reference pattern in order to determine said carrier frequency deviation; and

means for controlling said oscillator frequency based on said carrier frequency deviation.

In accordance with a fourth aspect, the present invention

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provides an apparatus for performing a coarse frequency synchronization compensation for a carrier frequency deviation from an oscillator frequency, for a demodulation system capable of demodulating a signal having a frame structure, said frame structure comprising at least one useful symbol and a reference symbol, said reference symbol being an amplitude-modulated bit sequence which comprises two identical sequences, said apparatus comprising:

receiving means for receiving said signal;

a down-converter for down-converting said received signal;

an amplitude-demodulator for performing an amplitude-demodulation of said down-converted signal in order to generate an envelope, said envelope having two portions which are based on said identical sequences;

a correlator for correlating one of said portions of said envelope with another one of said portions in order to determine said carrier frequency deviation; and

means for controlling said oscillator frequency based on said carrier frequency deviation.

The present invention provides a new scheme for a coarse frequency synchronization, in particular in MCM systems. The present invention is particularly useful in systems which use a differential coding and mapping along the frequency axis. In accordance with the present invention, the algorithm for the coarse frequency synchronization is based on a reference symbol which is formed by an amplitude-modulated

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performing the present invention as long as the transmitted signal comprises a useful portion and at least one reference symbol.

In order to obtain the final frame structure shown in Figure 4, a unit 116 for adding a reference symbol for each predetermined number of MCM symbols is provided.

In accordance with the present invention, the reference symbol is an amplitude modulated bit sequence. Thus, an amplitude modulation of a bit sequence is performed such that the envelope of the amplitude modulated bit sequence defines a reference pattern of the reference symbol. This reference pattern defined by the envelope of the amplitude modulated bit sequence has to be detected when receiving the MCM signal at a MCM receiver. In a preferred embodiment of the present invention, a pseudo random bit sequence having good autocorrelation properties is used as the bit sequence for the amplitude modulation.

The choice of length and repetition rate of the reference symbol depends on the properties of the channel through which the MCM signal is transmitted, e.g. the coherence time of the channel. In addition, the repetition rate and the length of the reference symbol, in other words the number of useful symbols in each frame, depends on the receiver requirements concerning mean time for initial synchronization and mean time for resynchronization after synchronization loss due to a channel fade.

The resulting MCM signal having the structure shown at 118 in Figure 1 is applied to the transmitter front end 120. Roughly ~~spoken~~ speaking, at the transmitter front end 120, a digital/analog conversion and an up-converting of the MCM signal is performed. Thereafter, the MCM signal is transmitted through a channel 122.

Following, the mode of operation of a MCM receiver 130 is

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offset of the carrier frequency with respect to the oscillator frequency in the MCM receiver is determined in oder to perform a frequency offset correction in a block 206. This frequency offset correction in block 206 is performed by a complex multiplication. The output of the frequency offset correction block 206 is applied to the MCM demodulator 208 formed by the Fast Fourier Transformator 140 and the carrier-bit mapper 142 shown in Figure 1.

In order to perform the inventive coarse frequency synchronization, in either case, an amplitude-demodulation has to be performed on a preprocessed MCM signal. The preprocessing may be, for example, the down-conversion and the analog/digital conversion of the MCM signal. The result of the amplitude-demodulation of the preprocessed MCM signal is an envelope representing the amplitude of the MCM signal.

For the amplitude demodulation a simple $\text{alpha}_{\text{max+}}$ $\text{beta}_{\text{min-}}$ method can be used. This method is described for example in ~~Palachels~~ Palacherla A.: DSP-~~mP~~ µP Routine Computes Magnitude, EDN, October 26, 1989; and Adams, W. T., and Bradley, J.: Magnitude Approximations for Microprocessor Implementation, IEEE Micro, Vol. 3, No. 5, October 1983.

It is clear that amplitude determining methods different from the described $\text{alpha}_{\text{max+}}$ $\text{beta}_{\text{min-}}$ method can be used. For simplification, it is possible to reduce the amplitude calculation to a detection as to whether the current amplitude is above or below the average amplitude. The output signal then consists of a -1/+1 sequence which can be used to determine a coarse frequency offset by performing a correlation. This correlation can easily be performed using a simple integrated circuit (IC).

In addition, an oversampling of the signal received at the RF front end can be performed. For example, the received signal can be expressed with two times oversampling.

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$$\Delta f = \frac{1}{2\pi T_{MCM}} \arg\left(\sum_{k=1}^{\frac{L}{2}} \tilde{r}(k) \cdot S^{*}_{AM}(k) \right) \qquad \text{(Eq.6)}$$

In accordance with a second embodiment of the coarse frequency synchronization algorithm in accordance with the present invention, a reference symbol comprising at least two identical sequences 300 as shown in Figure 3 is used. Figure 3 shows the reference symbol of a MCM signal having two identical sequences 300 of a length of L/2 each. L designates the number of values of the two sequences 300 of the reference symbol.

As shown in Figure 3, within the amplitude-modulated sequence, there are at least two identical sections devoted to the coarse frequency synchronization. Two such sections, each containing L/2 samples, are shown at the end of the amplitude-modulated sequence in Figure 3. The amplitude-modulated sequence contains a large number of samples. For a non-ambiguous observation of the phase, only enough samples to contain a phase rotation of 2π should be used. This number is defined as L/2 in Figure 3.

Following, a mathematical derivation of the determination of a carrier frequency deviation is presented. In accordance with Figure 3, the following equation applies for the two identical sequences 300:

$$s\left(0 < k \le \frac{L}{2}\right) \equiv s\left(\frac{L}{2} < k \le L\right) \qquad \text{(Eq.7)}$$

If no frequency offset is present, the following equation 8 will be met by the received signal:

$$r\left(k + \frac{L}{2}\right) \equiv r(k) \qquad 0 < k \le \frac{L}{2} \qquad \text{(Eq.8)}$$

r(k) designates the values of the identical sequences. k is an index from one to L/2 for the respective samples.

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sections.

A multiplier 428 is provided which multiplies the output of the correlator 406 by the output of the correlator 426. The output of the multiplier ~~425~~ 428 is connected to an argument operation unit 408. The output of the multiplier is applied to an argument operation unit 408, a multiplier 410 and an operation unit 412 in sequence. The mode of operation of these units corresponds to that of the corresponding units which are shown in Figure 5.

A alternative structure of an apparatus for performing the coarse frequency synchronization in accordance with the third embodiment of the present invention in the frequency domain is shown in Figure 7. As shown in Figure 7, a fast Fourier transformator 440 is provided between the demultiplexer 404 and a correlator 442, and a fast Fourier transformator 444 is provided between the demultiplexer 424 and a correlator 426. The outputs of the correlators 442 and 446 are connected to a multiplier ~~444~~ 445. The output of the multiplier ~~444~~ 445 is connected to a maximum searching unit ~~446~~ 447. Finally, a unit 448 for performing a $e^{-j(\pi\Delta f T_{MCM}/L)}$ operation is provided. The output of this unit 448 represents the output of the coarse frequency synchronization device.

In case of performing the coarse frequency synchronization in the frequency domain it is possible to make use of the existing FFT at the beginning of the detection for the coarse frequency synchronization rather than providing an additional fast Fourier transformator.

Following the course frequency synchronization described above, a fine frequency synchronization can be performed in case such a fine frequency synchronization is useful.

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CLAIMS

1. A method of performing a coarse frequency synchronization compensating for a carrier frequency deviation from an oscillator frequency in a demodulation system (130) capable of demodulating a signal having a frame structure comprising at least one useful symbol (162) and a reference symbol (166), said reference symbol (166) being an amplitude-modulated bit sequence, said method comprising the steps of:

receiving said signal;

down-converting said received signal;

performing an amplitude-demodulation of said down-converted signal in order to generate an envelope;

correlating said envelope with a predetermined reference pattern in order to determine said carrier frequency deviation; and

controlling said oscillator frequency based on said carrier frequency deviation.

2. The method of claim 1, wherein said carrier frequency deviation is determined as follows:

$$\Delta f = \frac{1}{2\pi T_{MCM}} \arg\left(\sum_{k=1}^{\frac{L}{2}} \tilde{r}(k) \cdot S^{*}_{AM}(k) \right) \qquad \text{(Eq.6)}$$

wherein $\tilde{r}$ designates values of said envelope of the received signal;

S^{*}_{AM} designates the complex conjugate of the values of the predetermined reference pattern;

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T_{MCM} designates the duration of said useful symbol;

k designates an index; and

L/2 designates the half length of the sequence used for the coarse frequency synchronization.

3. A method of performing a coarse frequency synchronization compensation for a carrier frequency deviation from an oscillator frequency in a demodulation system (130) capable of demodulating a signal having a frame structure, said frame structure comprising at least one useful symbol (162) and a reference symbol (166), said reference symbol (166) being an amplitude-modulated bit sequence which comprises two identical sequences (300), said method comprising the steps of:

receiving said signal;

down-converting said received signal;

performing an amplitude-demodulation of the down-converted signal in order to generate an envelope, said envelope having two portions which are based on said identical sequences (300);

correlating one of said portions of said envelope with another one of said portions in order to determine said carrier frequency deviation; and

controlling said oscillator frequency based on said carrier frequency deviation.

4. The method of claim 3, wherein said correlating step further comprises weighting of corresponding values of said two portions with corresponding values of said two sequences.

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5. The method of claim 3, wherein said carrier frequency deviation is determined as follows:

$$\Delta f = \frac{1}{2\pi \frac{L}{2} T_{MCM}} \arg\left(\sum_{k=1}^{\frac{L}{2}} \tilde{r}\left(k+\frac{L}{2}\right) \cdot \tilde{r}^{*}(k) \right) \qquad \text{(Eq.13)}$$

wherein $\tilde{r}$ designates values of said portions;

$\tilde{r}^{*}$ designates the complex conjugate of said values of said portions;

T_{MCM} designates the duration of said useful symbol;

k designates an index; and

L designates the number of values of said two sequences of said reference symbol.

6. The method of claim 4, wherein said carrier frequency deviation is determined as follows:

$$\Delta f = \frac{1}{2\pi \frac{L}{2} T_{MCM}} \arg\left(\sum_{k=1}^{\frac{L}{2}} \left[\tilde{r}\left(k+\frac{L}{2}\right) \cdot \tilde{r}^{*}(k) \right] \cdot \left[S_{AM}(k) S_{AM}^{*}\left(k+\frac{L}{2}\right) \right] \right) \qquad \text{(Eq.14)}$$

wherein $\tilde{r}$ designates values of said portions;

$\tilde{r}^{*}$ designates the complex conjugate of said values of said portions;

T_{MCM} designates the duration of said useful symbol;

k designates an index;

L designates the number of values of said two sequences of said reference symbol;

S_{AM} designates values of said identical sequences; and

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S^*_{AM} designates the complex conjugate of said values of said identical sequences.

7. The method according one of claims 1 to 6, wherein said signal is an orthogonal frequency division multiplex signal.

8. The method according to one of claims 1 to 7, further comprising the step of performing a fast automatic gain control of said received down-converted signal prior to the step of performing said amplitude-demodulation.

9. The method according to one of claims 1 to 8, wherein the step of performing said amplitude-demodulation comprises the step of calculating an amplitude of said signal using the $alpha_{max+}$ $beta_{min-}$ method.

10. The method according to one of claims 1 to 9, further comprising the steps of sampling respective amplitudes of said received down-converted signal and comparing said sampled amplitudes with a predetermined threshold in order to generate a bit sequence in order to perform said amplitude-demodulation.

11. The method according to claim 10, wherein the step of sampling respective amplitudes of said received down-converted signal further comprises the step of performing an over-sampling of said received down-converted signal.

12. An apparatus for performing a coarse frequency synchronization compensating for a carrier frequency deviation from an oscillator frequency, for a demodulation system (130) capable of demodulating a signal having a frame structure, said frame structure comprising at least one useful symbol (162) and a reference symbol (166), said reference symbol being an amplitude-modulated bit sequence, said apparatus comprising:

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receiving means (132) for receiving said signal;

a down-converter for down-converting said received signal;

an amplitude-demodulator for performing an amplitude-demodulation of said down-converted signal in order to generate an envelope;

a correlator for correlating said envelope with a predetermined reference pattern in order to determine said carrier frequency deviation; and

means for controlling said oscillator frequency based on said carrier frequency deviation.

13. The apparatus of claim 12, comprising means for determining said carrier frequency deviation as follows:

$$\Delta f = \frac{1}{2\pi T_{MCM}} \arg\left(\sum_{k=1}^{\frac{L}{2}} \tilde{r}(k) \cdot S^{*}_{AM}(k) \right) \qquad \text{(Eq.6)}$$

wherein $\tilde{r}$ designates values of said envelope of the received signal;

S^{*}_{AM} designates the complex conjugate of the values of the predetermined reference pattern;

T_{MCM} designates the duration of said useful symbol;

k designates an index; and

L/2 designates the number of values of the reference pattern.

14. An apparatus for performing a coarse frequency synchronization compensation for a carrier frequency deviation from an oscillator frequency, for a demodulation

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system (130) capable of demodulating a signal having a frame structure, said frame structure comprising at least one useful symbol (162) and a reference symbol (166), said reference symbol (166) being an amplitude-modulated bit sequence which comprises two identical sequences (300), said apparatus comprising:

receiving means (132) for receiving said signal;

a down-converter for down-converting said received signal;

an amplitude-demodulator for performing an amplitude-demodulation of said down-converted signal in order to generate an envelope, said envelope having two portions which are based on said identical sequences (300);

a correlator for correlating one of said portions of said envelope with another one of said portions in order to determine said carrier frequency deviation; and

means for controlling said oscillator frequency based on said carrier frequency deviation.

15. The apparatus of claim 14, wherein said correlator comprises means for weighting of corresponding values of said two portions with corresponding values of said two sequences (300).

16. The apparatus of claim 14, comprising means for determining said carrier frequency deviation as follows:

$$\Delta f = \frac{1}{2\pi \frac{L}{2} T_{MCM}} \arg\left(\sum_{k=1}^{\frac{L}{2}} \tilde{r}\left(k + \frac{L}{2}\right) \cdot \tilde{r}^{*}(k) \right) \qquad \text{(Eq.13)}$$

wherein r designates values of said portions;

r^* designates the complex conjugate of said values of

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said portions;

T_{MCM} designates the duration of said useful symbol;

k designates an index; and

L designates the number of values of said two sequences of said reference symbol.

17. The apparatus of claim 15, comprising means for determining said carrier frequency deviation as follows:

$$\Delta f = \frac{1}{2\pi \frac{L}{2} T_{MCM}} \arg\left(\sum_{k=1}^{\frac{L}{2}} \left[\tilde{r}\left(k+\frac{L}{2}\right) \cdot \tilde{r}^{*}(k) \right] \cdot \left[S_{AM}(k) S_{AM}^{*}\left(k+\frac{L}{2}\right) \right] \right) \quad \text{(Eq.14)}$$

wherein $\tilde{r}$ designates values of said portions;

$\tilde{r}^{*}$ designates the complex conjugate of said values of said portions;

T_{MCM} designates the duration of said useful symbol;

k designates an index;

L designates the number of values of said two sequences of said reference symbol;

S_{AM} designates values of said identical sequences; and

S^{*}_{AM} designates the complex conjugate of said values of said identical sequences.

18. The apparatus according to one of claims 13 to 17, wherein said signal is an orthogonal frequency division multiplexed signal.

19. The apparatus according to one of claims 13 to 18,

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further comprising means for performing a fast automatic gain control of said received down-converted signal preceding said amplitude-demodulator.

20. The apparatus according to one of claims 13 to 18, wherein said amplitude-demodulator comprises means for calculating an amplitude of said signal using the $alpha_{max+}$ $beta_{min-}$ method.

21. The apparatus according to one of claims 13 to 20, further comprising means for sampling respective amplitudes of said received down-converted signal, wherein said amplitude-demodulator comprises means for comparing said sampled amplitudes with a predetermined threshold in order to generate a bit sequence.

22. The apparatus according to claim 21, wherein said means for sampling comprises means for over-sampling said received down-converted signal.

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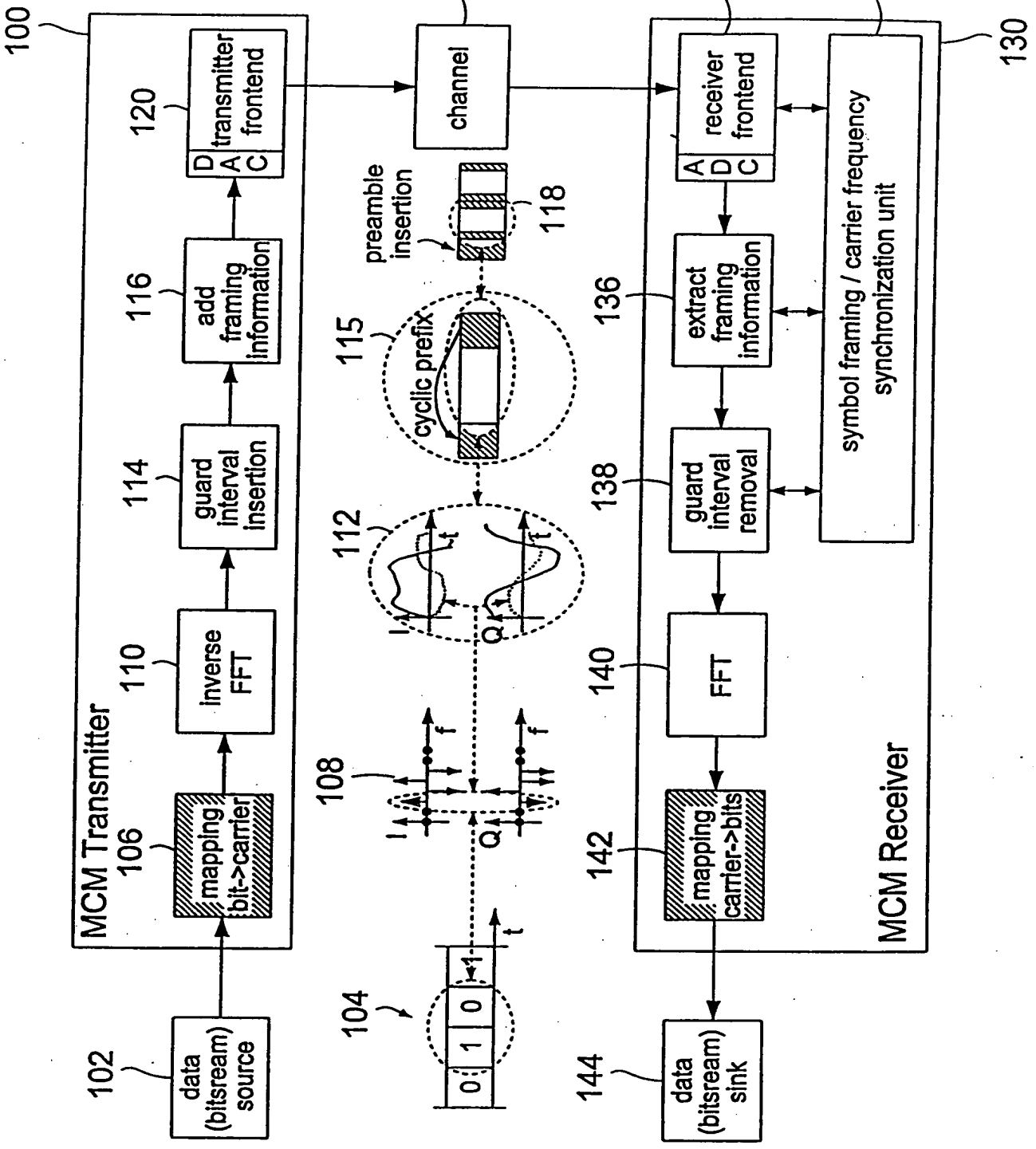

FIG.1

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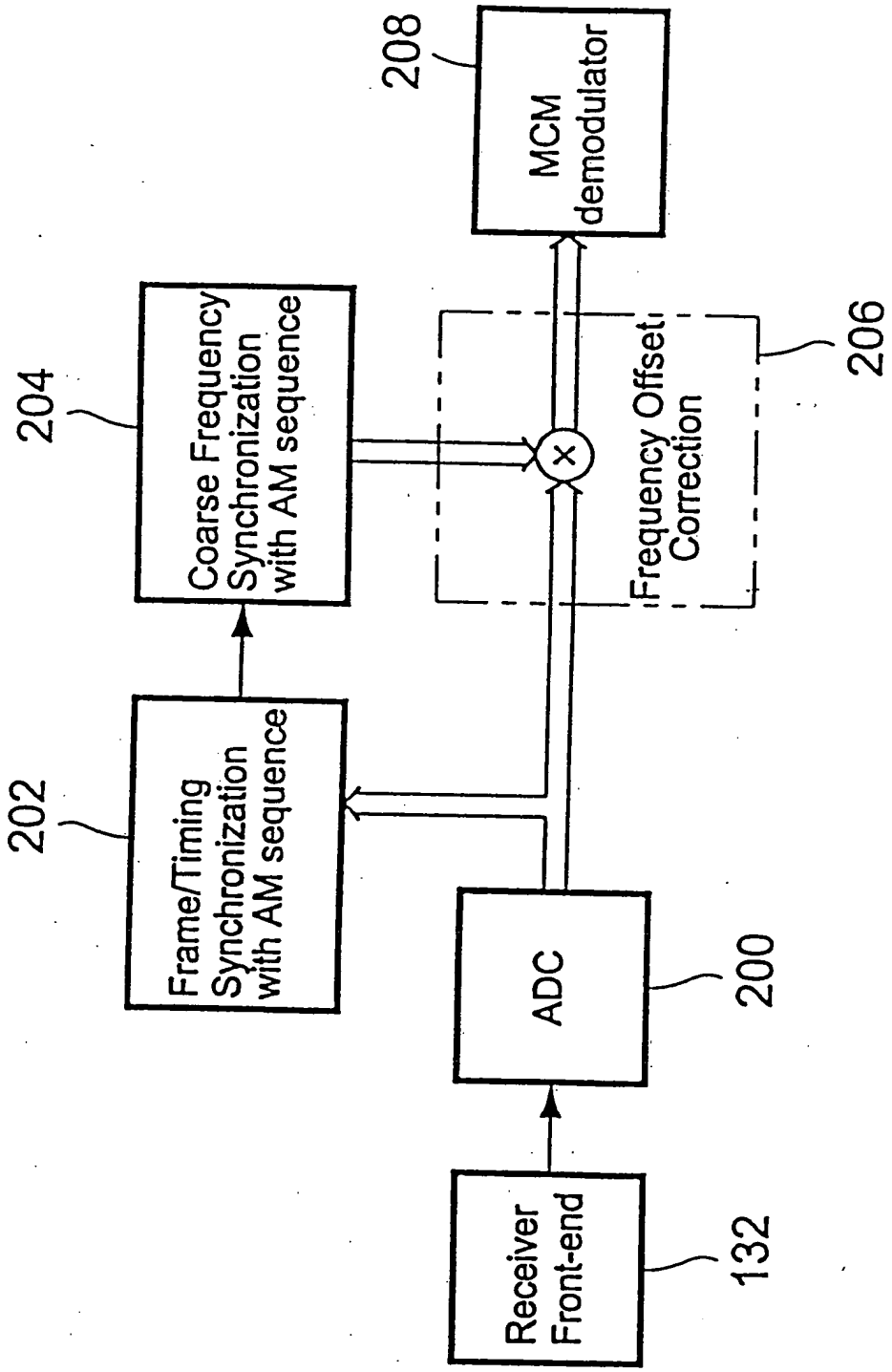

FIG.2

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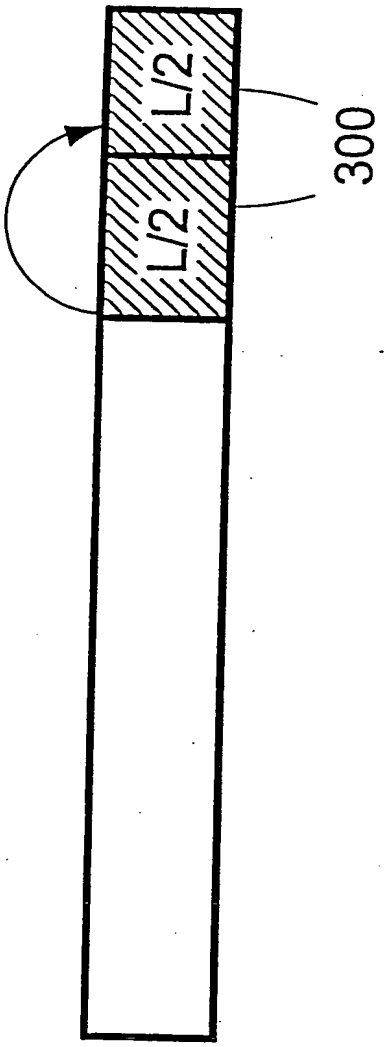

FIG.3

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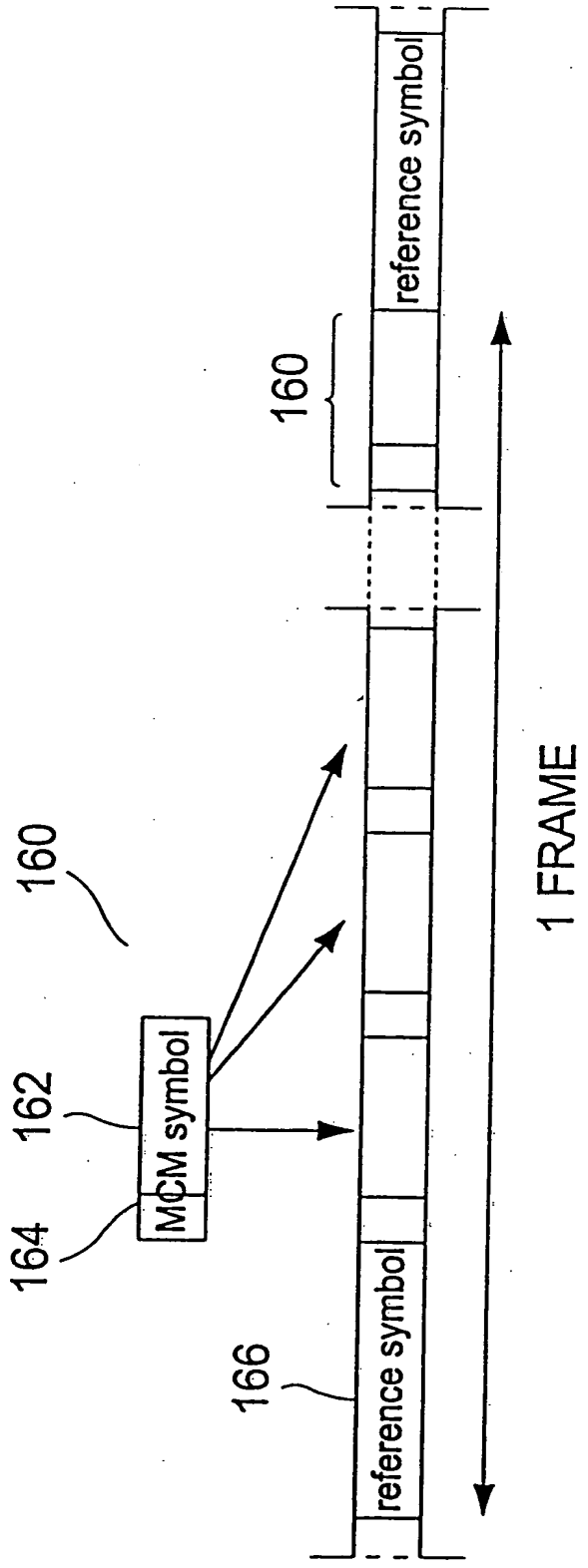

FIG.4

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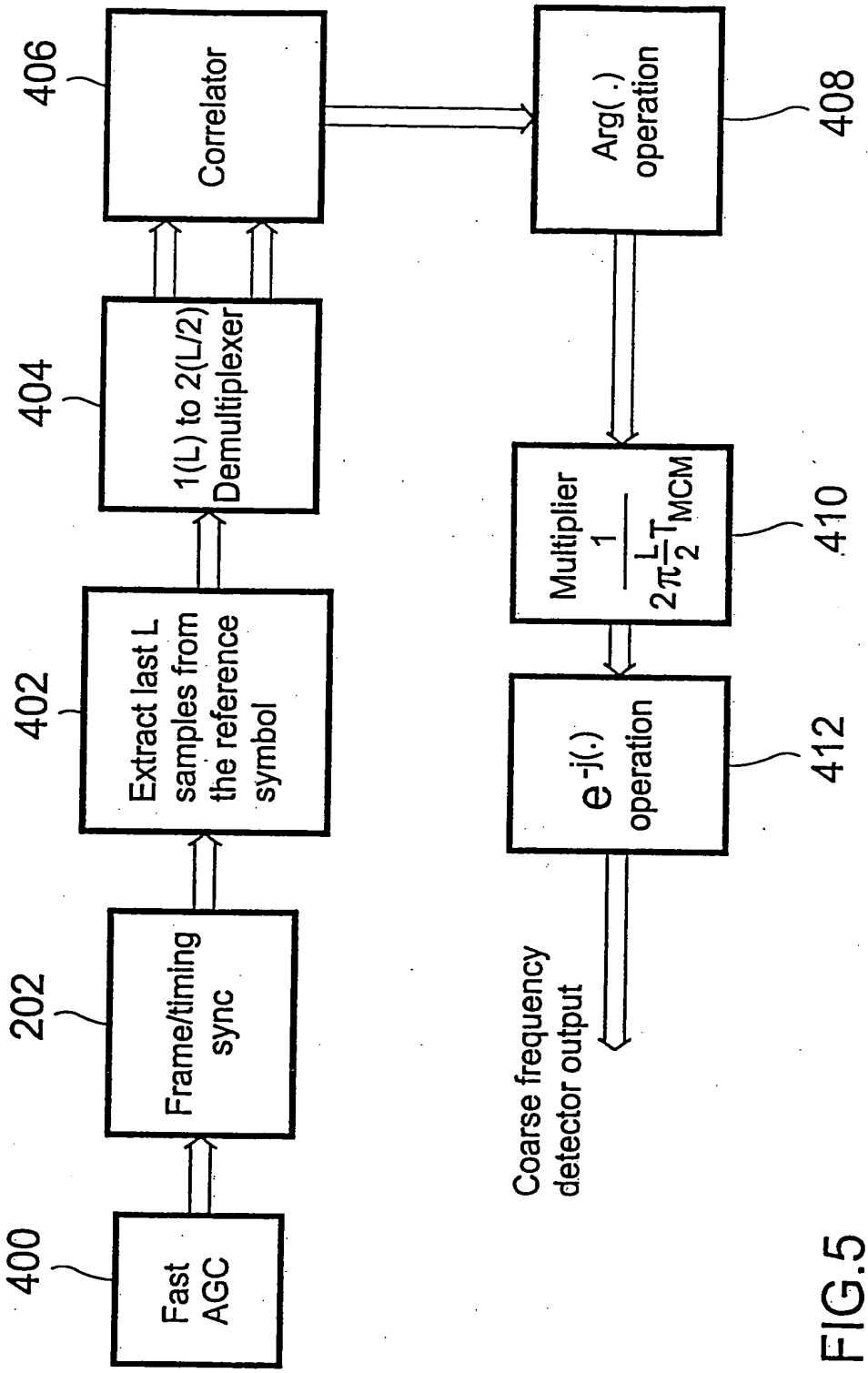

FIG.5

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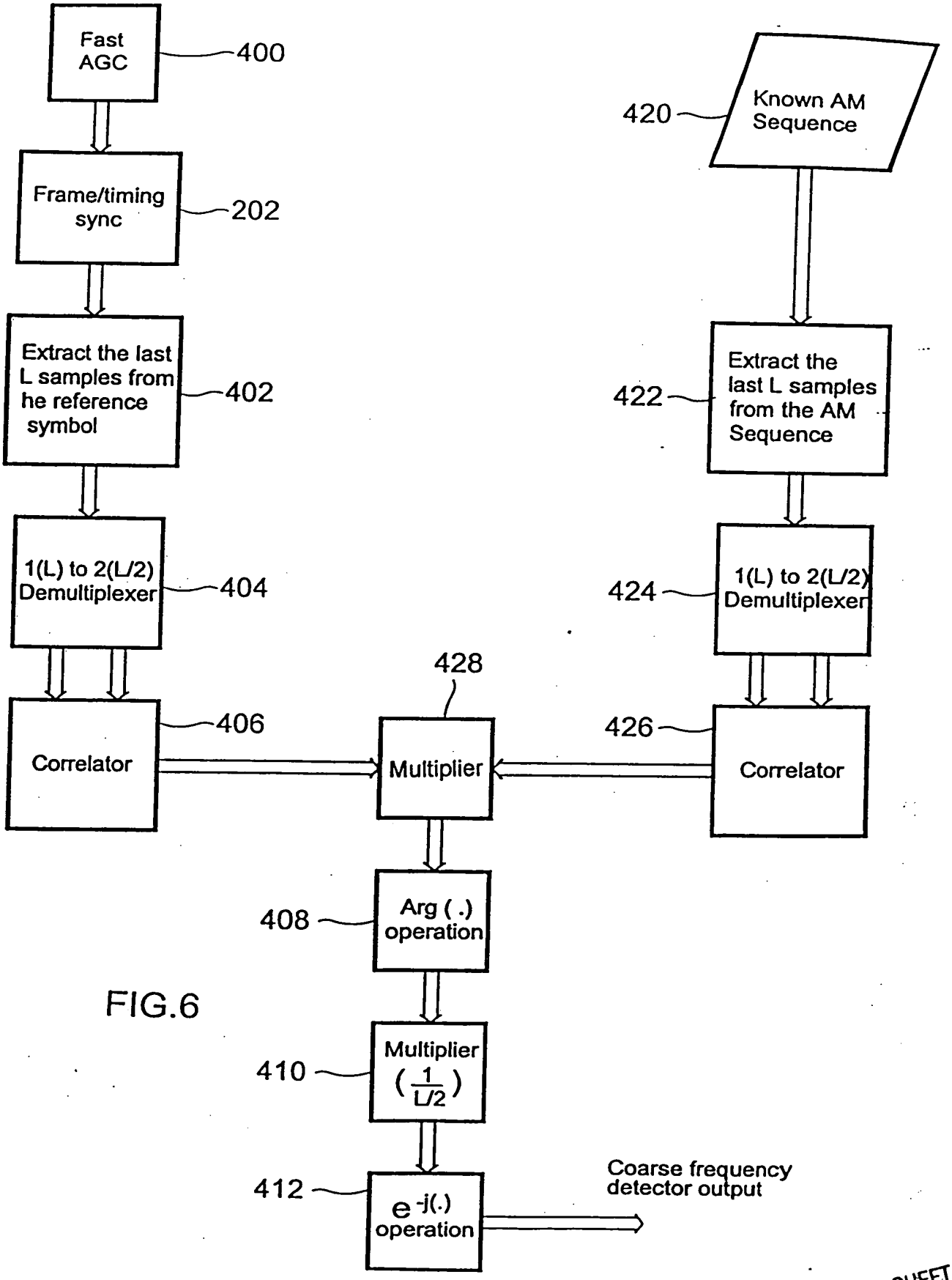

FIG.6

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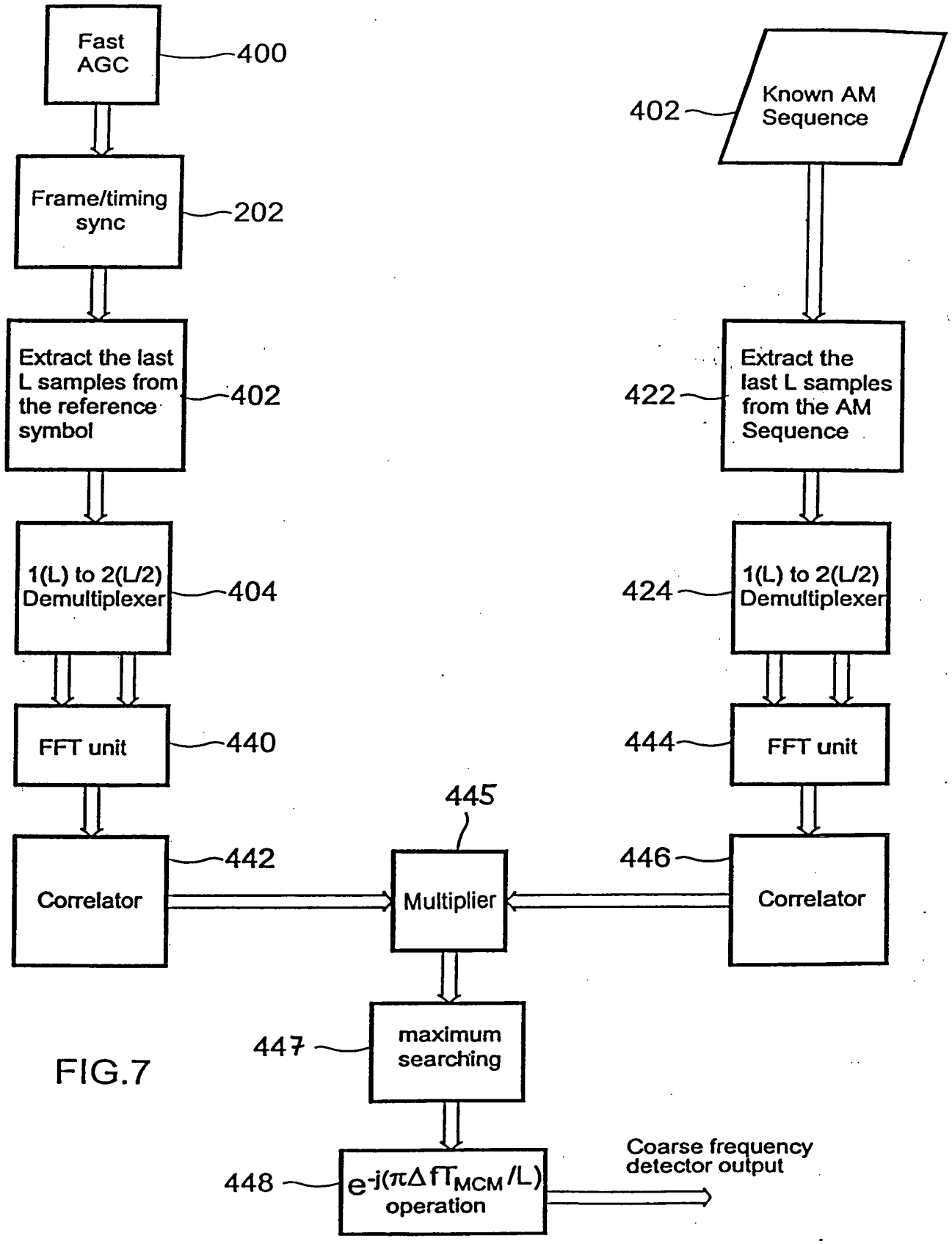

FIG.7

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PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT OR THE DECLARATION

(PCT Rule 44.1)

To:
SCHOPPE & ZIMMERMANN
Postfach 71 08 67
D-81458 München
GERMANY

Date of mailing *(day/month/year)* 12/01/1999	
Applicant's or agent's file reference FH980403PCT	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/EP 98/ 02170	International filing date *(day/month/year)* 14/04/1998
Applicant FRAUNHOFER-GESELLSCHAFT ZUR FÖRDERUNG ... et al.	

1. [X] The applicant is hereby notified that the International Search Report has been established and is transmitted herewith.

   Filing of amendments and statement under Article 19
   The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 46):

   When? The time limit for filing such amendments is normally 2 months from the date of transmittal of the International Search Report; however, for more details, see the notes on the accompanying sheet.

   Where? Directly to the International Bureau of WIPO
   34, chemin des Colombettes
   1211 Geneva 20, Switzerland
   Fascimile No.: (41-22) 740.14.35

   For more detailed instructions, see the notes on the accompanying sheet.

2. [ ] The applicant is hereby notified that no International Search Report will be established and that the declaration under Article 17(2)(a) to that effect is transmitted herewith.

3. [ ] **With regard to the protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

   [ ] the protest together with the decision thereon has been transmitted to the International Bureau together with the applicants's request to forward the texts of both the protest and the decision thereon to the designated Offices.

   [ ] no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Further action(s):** The applicant is reminded of the following:

   Shortly after **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90*bis*.1 and 90*bis*.3, respectively, before the completion of the technical preparations for international publication.

   Within **19 months** from the priority date, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later).

   Within **20 months** from the priority date, the applicant must perform the prescribed acts for entry into the national phase before all designated Offices which have not been elected in the demand or in a later election within 19 months from the priority date or could not be elected because they are not bound by Chapter II.

Name and mailing address of the International Searching Authority	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	René Stolk

Form PCT/ISA/220 (January 1994)

NOTES TO FORM PCT/ISA/220

These Notes are intended to give the basic instructions concerning the filing of amendments under article 19. The Notes are based on the requirements of the Patent Cooperation Treaty, the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the PCT Applicant's Guide, a publication of WIPO.

In these Notes, "Article", "Rule", and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions respectively.

INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims, description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the latter to be published for the purposes of provisional protection or has another reason for amending the claims before international publication. Furthermore, it should be emphasized that provisional protection is available in some States only.

What parts of the international application may be amended?

Under Article 19, only the claims may be amended.

During the international phase, the claims may also be amended (or further amended) under Article 34 before the International Preliminary Examining Authority. The description and drawings may only be amended under Article 34 before the International Examining Authority.

Upon entry into the national phase, all parts of the international application may be amended under Article 28 or, where applicable, Article 41.

When? Within 2 months from the date of transmittal of the international search report or 16 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the International Bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

Where not to file the amendments?

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 46.2).

Where a demand for international preliminary examination has been/is filed, see below.

How? Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed.

A replacement sheet must be submitted for each sheet of the claims which, on account of an amendment or amendments, differs from the sheet originally filed.

All the claims appearing on a replacement sheet must be numbered in Arabic numerals. Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively (Administrative Instructions, Section 205(b)).

The amendments must be made in the language in which the international application is to be published.

What documents must/may accompany the amendments?

Letter (Section 205(b)):

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confused with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

The letter must be in English or French, at the choice of the applicant. However, if the language of the international application is English, the letter must be in English; if the language of the international application is French, the letter must be in French.

The letter must indicate the differences between the claims as filed and the claims as amended. It must, in particular, indicate, in connection with each claim appearing in the international application (it being understood that identical indications concerning several claims may be grouped),whether

(i) the claim is unchanged;

(ii) the claim is cancelled;

(iii) the claim is new;

(iv) the claim replaces one or more claims as filed;

(v) the claim is the result of the division of a claim as filed.

The following examples illustrate the manner in which amendments must be explained in the accompanying letter:

1. [Where originally there were 48 claims and after amendment of some claims there are 51]:
"Claims 1 to 29, 31, 32, 34, 35, 37 to 48 replaced by amended claims bearing the same numbers; claims 30, 33 and 36 unchanged; new claims 49 to 51 added."

2. [Where originally there were 15 claims and after amendment of all claims there are 11]:
"Claims 1 to 15 replaced by amended claims 1 to 11."

3. [Where originally there were 14 claims and the amendments consist in cancelling some claims and in adding new claims]:
"Claims 1 to 6 and 14 unchanged; claims 7 to 13 cancelled; new claims 15, 16 and 17 added." or
"Claims 7 to 13 cancelled; new claims 15, 16 and 17 added; all other claims unchanged."

4. [Where various kinds of amendments are made]:
"Claims 1-10 unchanged; claims 11 to 13, 18 and 19 cancelled; claims 14, 15 and 16 replaced by amended claim 14; claim 17 subdivided into amended claims 15, 16 and 17; new claims 20 and 21 added."

"Statement under article 19(1)" (Rule 46.4)

The amendments may be accompanied by a statement explaining the amendments and indicating any impact that such amendments might have on the description and the drawings (which cannot be amended under Article 19(1)).

The statement will be published with the international application and the amended claims.

It must be in the language in which the international appplication is to be published.

It must be brief, not exceeding 500 words if in English or if translated into English.

It should not be confused with and does not replace the letter indicating the differences between the claims as filed and as amended. It must be filed on a separate sheet and must be identified as such by a heading, preferably by using the words "Statement under Article 19(1)."

It may not contain any disparaging comments on the international search report or the relevance of citations contained in that report. Reference to citations, relevant to a given claim, contained in the international search report may be made only in connection with an amendment of that claim.

Consequence if a demand for international preliminary examination has already been filed

If, at the time of filing any amendments under Article 19, a demand for international preliminary examination has already been submitted, the applicant must preferably, at the same time of filing the amendments with the International Bureau, also file a copy of such amendments with the International Preliminary Examining Authority (see Rule 62.2(a), first sentence).

Consequence with regard to translation of the international application for entry into the national phase

The applicant's attention is drawn to the fact that, where upon entry into the national phase, a translation of the claims as amended under Article 19 may have to be furnished to the designated/elected Offices, instead of, or in addition to, the translation of the claims as filed.

For further details on the requirements of each designated/elected Office, see Volume II of the PCT Applicant's Guide.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
FH980403PCT		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/EP 98/ 02170	14/04/1998	
Applicant		
FRAUNHOFER-GESELLSCHAFT ZUR FÖRDERUNG ... et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. [ ] **Certain claims were found unsearchable** (see Box I).

2. [ ] **Unity of invention is lacking** (see Box II).

3. [ ] The international application contains disclosure of a **nucleotide and/or amino acid sequence listing** and the international search was carried out on the basis of the sequence listing
   - [ ] filed with the international application.
   - [ ] furnished by the applicant separately from the international application,
     - [ ] but not accompanied by a statement to the effect that it did not include matter going beyond the disclosure in the international application as filed.
   - [ ] Transcribed by this Authority

4. With regard to the **title,**
   - [ ] the text is approved as submitted by the applicant
   - [X] the text has been established by this Authority to read as follows:

   FRAME STRUCTURE AND FRAME SYNCHRONISATION FOR MULTICARRIER SYSTEMS

5. With regard to the **abstract,**
   - [X] the text is approved as submitted by the applicant
   - [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this International Search Report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is:
   Figure No. 4
   - [X] as suggested by the applicant.
   - [ ] because the applicant failed to suggest a figure.
   - [ ] because this figure better characterizes the invention.
   - [ ] None of the figures.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 98/02170

A. CLASSIFICATION OF SUBJECT MAT
IPC 6 H04L27/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 98 00946 A (LELAND STANFORD JUNIOR UNIVERSITY) 8 January 1998 see page 17, line 16 - line 22 see page 26, line 17 - page 27, line 2 see page 27, line 14 - line 24 see page 28, line 4 - line 16 --- -/--	1,3,12, 14

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
5 January 1999	12/01/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Scriven, P

1

Form PCT/ISA/210 (second sheet) (July 1992)

International Application No
PCT/EP 98/02170

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	MOOSE: "A technique for orthogonal frequency division multiplexing frequency offset correction" IEEE TRANSACTIONS ON COMMUNICATIONS., vol. 42, no. 10, October 1994, pages 2908-2914, XP002019915 NEW YORK, US cited in the application see page 2908, right-hand column, paragraph 5 see page 2911, right-hand column, paragraph 5 - page 2912, right-hand column, paragraph 2 ---	1,3,12, 14
A	KELLER; HANZO: "Orthogonal frequency division muliplex synchronisation techniques for wireless local area networks" IEEE INTERNATIONAL SYMPOSIUM ON PERSONAL, INDOOR AND MOBILE RADIO COMMUNICATIONS, 15 October 1996, pages 963-967, XP002063294 New York, US see page 963, right-hand column, paragraph 3 -----	1,3,12, 14

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 98/02170

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9800946 A	08-01-1998	US 5732113 A	24-03-1998

PATENT COOPERATION TREATY

PCT

REC'D 23 AUG 2000
WIPO PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
FH980403PCT		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/EP98/02170	14/04/1998	[14/04/1998]
International Patent Classification (IPC) or national classification and IPC		
H04L27/26		
Applicant		
FRAUNHOFER-GESELLSCHAFT...		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 5 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 23 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
22/07/1999	18.08.00
Name and mailing address of the international preliminary examining authority:	Authorized officer
European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Snell, T Telephone No. +49 89 2399 8802

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/EP98/02170

I. Basis of the report

1. This report has been drawn on the basis of (*substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.*):

Description, pages:

1,2,6-8,10,11,13, 15-17	as originally filed			
3-5,5a,9,12,14, 18	as received on	07/03/2000	with letter of	07/03/2000

Claims, No.:

1-22	as received on	07/03/2000	with letter of	07/03/2000

Drawings, sheets:

1/7-7/7	as received on	07/03/2000	with letter of	07/03/2000

2. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:
- ☐ the drawings, sheets:

3. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

4. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-22
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-22
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-22
	No:	Claims	

2. Citations and explanations

see separate sheet

Cited document

D1: WO 98 00946 A (LELAND STANFORD JUNIOR UNIVERSITY) 8th January 1998

Re Item V

Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. The invention relates to a method (independent claims 1 and 3) of performing a coarse frequency synchronisation, for example in an OFDM environment, and a corresponding apparatus for carrying out the method (independent claims 12 and 14).

2. The closest prior art document D1 describes such a method, whereby two training symbols are placed into the OFDM frame, at least once every frame. The first training symbol is produced by modulating the even-numbered OFDM sub-carriers and suppressing the odd-numbered carriers, and the second training symbol is produced by modulating the odd-numbered OFDM sub-carriers and suppressing the even-numbered carriers. The modulation signal is a pseudo-noise signal. The synchronisation process is bound up with the decoding of the OFDM signal, as fast Fourier transforms of the two training signals are required.

3. According to the invention, a reference symbol placed in every frame comprises an amplitude modulated bit sequence. In order to perform the synchronisation an amplitude demodulation of the received and down-converted signal is performed, and correlated with a stored pattern. Thereby, in contrast to D1, synchronisation can be obtained before beginning with the decoding of the OFDM signal.

   As neither D1 nor the other documents cited in the international search report gives no hint to use amplitude demodulation prior to OFDM decoding to obtain coarse synchronisation, the subject-matter of claim 1 is novel and involves an inventive step (Articles 33(1)-(3) PCT).

4. Method claim 3 relates to a further embodiment using two identical symbols, but

still based on the same inventive concept. Apparatus claims 12 and 14 correspond to method claims 1 and 3. The subject-matter of claims 3, 12 and 14 is therefore also novel and involves an inventive step (Articles 33(1)-(3) PCT).

5. Claims 2, 4-11, 13 and 15-22 are all dependent on one of the independent claims 1, 3, 12 or 14 and thus also meet the requirements for novelty and inventive step (Articles 33(1)-(3) PCT).

REPLACED BY ART 34 AMDT

SUMMARY OF THE INVENTION

It is an object of the present invention to provide methods and apparatus for performing a coarse frequency synchronization even in the case of frequency offsets that correspond to a multiple of the subcarrier distance in a MCM signal.

In accordance with a first aspect, the present invention provides a method of performing a coarse frequency synchronization compensating for a carrier frequency deviation from an oscillator frequency in a demodulation system capable of demodulating a signal having a frame structure, said frame structure comprising at least one useful symbol and a reference symbol, said reference symbol being an amplitude-modulated sequence, the method comprising the steps of:

receiving the signal;

down-converting the received signal;

performing an amplitude-demodulation of the down-converted signal in order to generate an envelope;

correlating the envelope with a predetermined reference pattern in order to determine the carrier frequency deviation; and

controlling the oscillator frequency based on the carrier frequency deviation.

In accordance with a second aspect, the present invention provides a method of performing a coarse frequency synchronization compensating for a carrier frequency deviation from an oscillator frequency in a demodulation system capable of demodulating a signal having a frame structure, the frame structure comprising at least one useful symbol and a reference symbol, the reference symbol being an amplitude-

modulated sequence which comprises two identical sequences, the method comprising the steps of:

receiving the signal;

down-converting the received signal;

performing an amplitude-demodulation of the down-converted signal in order to generate an envelope, the envelope having two portions which are based on the identical sequences;

correlating one of the portions of the envelope with another one of the portions in order to determine the carrier frequency deviation; and

controlling the oscillator frequency based on the carrier frequency deviation.

In accordance with a third aspect, the present invention provides an apparatus for performing a coarse frequency synchronization compensating for a carrier frequency deviation from an oscillator frequency, for a demodulation system capable of demodulating a signal having a frame structure, the frame structure comprising at least one useful symbol and a reference symbol, the reference symbol being an amplitude-modulated sequence, the apparatus comprising:

receiving means for receiving the signal;

a down-converter for down-converting the received signal;

an amplitude-demodulator for performing an amplitude-demodulation of the down-converted signal in order to generate an envelope;

a correlator for correlating the envelope with a predetermined reference pattern in order to determine the carrier

frequency deviation; and

means for controlling the oscillator frequency based on the carrier frequency deviation.

In accordance with a fourth aspect, the present invention provides an apparatus for performing a coarse frequency synchronization compensating for a carrier frequency deviation from an oscillator frequency, for a demodulation system capable of demodulating a signal having a frame structure, the frame structure comprising at least one useful symbol and a reference symbol, the reference symbol being an amplitude-modulated sequence which comprises two identical sequences, the apparatus comprising:

receiving means for receiving the signal;

a down-converter for down-converting the received signal;

an amplitude-demodulator for performing an amplitude-demodulation of the down-converted signal in order to generate an envelope, the envelope having two portions which are based on the identical sequences;

a correlator for correlating one of the portions of the envelope with another one of the portions in order to determine the carrier frequency deviation; and

means for controlling the oscillator frequency based on the carrier frequency deviation.

The present invention provides a new scheme for a coarse frequency synchronization, in particular in MCM systems. The present invention is particularly useful in systems which use a differential coding and mapping along the frequency axis. In accordance with the present invention, the algorithm for the coarse frequency synchronization is based on a reference symbol which is formed by an amplitude-modulated

performing the present invention as long as the transmitted signal comprises a useful portion and at least one reference symbol.

In order to obtain the final frame structure shown in Figure 4, a unit 116 for adding a reference symbol for each predetermined number of MCM symbols is provided.

In accordance with the present invention, the reference symbol is an amplitude modulated bit sequence. Thus, an amplitude modulation of a bit sequence is performed such that the envelope of the amplitude modulated bit sequence defines a reference pattern of the reference symbol. This reference pattern defined by the envelope of the amplitude modulated bit sequence has to be detected when receiving the MCM signal at a MCM receiver. In a preferred embodiment of the present invention, a pseudo random bit sequence having good autocorrelation properties is used as the bit sequence for the amplitude modulation.

The choice of length and repetition rate of the reference symbol depends on the properties of the channel through which the MCM signal is transmitted, e.g. the coherence time of the channel. In addition, the repetition rate and the length of the reference symbol, in other words the number of useful symbols in each frame, depends on the receiver requirements concerning mean time for initial synchronization and mean time for resynchronization after synchronization loss due to a channel fade.

The resulting MCM signal having the structure shown at 118 in Figure 1 is applied to the transmitter front end 120. Roughly spoken, at the transmitter front end 120, a digital/analog conversion and an up-converting of the MCM signal is performed. Thereafter, the MCM signal is transmitted through a channel 122.

Following, the mode of operation of a MCM receiver 130 is

offset of the carrier frequency with respect to the oscillator frequency in the MCM receiver is determined in oder to perform a frequency offset correction in a block 206. This frequency offset correction in block 206 is performed by a complex multiplication. The output of the frequency offset correction block 206 is applied to the MCM demodulator 208 formed by the Fast Fourier Transformator 140 and the carrier-bit mapper 142 shown in Figure 1.

In order to perform the inventive coarse frequency synchronization, in either case, an amplitude-demodulation has to be performed on a preprocessed MCM signal. The preprocessing may be, for example, the down-conversion and the analog/digital conversion of the MCM signal. The result of the amplitude-demodulation of the preprocessed MCM signal is an envelope representing the amplitude of the MCM signal.

For the amplitude demodulation a simple $alpha_{max+}$ $beta_{min-}$ method can be used. This method is described for example in Palachels A.: DSP-mP Routine Computes Magnitude, EDN, October 26, 1989; and Adams, W. T., and Bradley, J.: Magnitude Approximations for Microprocessor Implementation, IEEE Micro, Vol. 3, No. 5, October 1983.

It is clear that amplitude determining methods different from the described $alpha_{max+}$ $beta_{min-}$ method can be used. For simplification, it is possible to reduce the amplitude calculation to a detection as to whether the current amplitude is above or below the average amplitude. The output signal then consists of a -1/+1 sequence which can be used to determine a coarse frequency offset by performing a correlation. This correlation can easily be performed using a simple integrated circuit (IC).

In addition, an oversampling of the signal received at the RF front end can be performed. For example, the received signal can be expressed with two times oversampling.

$$\Delta f = \frac{1}{2\pi T_{MCM}} \arg\left(\sum_{k=1}^{\frac{L}{2}} \tilde{r}(k) \cdot S_{AM}^{*} \right) \qquad \text{(Eq.6)}$$

In accordance with a second embodiment of the coarse frequency synchronization algorithm in accordance with the present invention, a reference symbol comprising at least two identical sequences 300 as shown in Figure 3 is used. Figure 3 shows the reference symbol of a MCM signal having two identical sequences 300 of a length of L/2 each. L designates the number of values of the two sequences 300 of the reference symbol.

As shown in Figure 3, within the amplitude-modulated sequence, there are at least two identical sections devoted to the coarse frequency synchronization. Two such sections, each containing L/2 samples, are shown at the end of the amplitude-modulated sequence in Figure 3. The amplitude-modulated sequence contains a large number of samples. For a non-ambiguous observation of the phase, only enough samples to contain a phase rotation of 2π should be used. This number is defined as L/2 in Figure 3.

Following, a mathematical derivation of the determination of a carrier frequency deviation is presented. In accordance with Figure 3, the following equation applies for the two identical sequences 300:

$$s\left(0 < k \leq \frac{L}{2}\right) \equiv s\left(\frac{L}{2} < k \leq L\right) \qquad \text{(Eq.7)}$$

If no frequency offset is present, the following equation 8 will be met by the received signal:

$$r\left(k + \frac{L}{2}\right) \equiv r(k) \qquad 0 < k \leq \frac{L}{2} \qquad \text{(Eq.8)}$$

r(k) designates the values of the identical sequences. k is an index from one to L/2 for the respective samples.

sections.

A multiplier 428 is provided which multiplies the output of the correlator 406 by the output of the correlator 426. The output of the multiplier 425 is connected to an argument operation unit 408. The output of the multiplier is applied to an argument operation unit 408, a multiplier 410 and an operation unit 412 in sequence. The mode of operation of these units corresponds to that of the corresponding units which are shown in Figure 5.

A alternative structure of an apparatus for performing the coarse frequency synchronization in accordance with the third embodiment of the present invention in the frequency domain is shown in Figure 7. As shown in Figure 7, a fast Fourier transformator 440 is provided between the demultiplexer 404 and a correlator 442, and a fast Fourier transformator 444 is provided between the demultiplexer 424 and a correlator 426. The outputs of the correlators 442 and 446 are connected to a multiplier 444. The output of the multiplier 444 is connected to a maximum searching unit 446. Finally, a unit 448 for performing a $e^{-j(\pi\Delta f T_{MCM}/L)}$ operation is provided. The output of this unit 448 represents the output of the coarse frequency synchronization device.

In case of performing the coarse frequency synchronization in the frequency domain it is possible to make use of the existing FFT at the beginning of the detection for the coarse frequency synchronization rather than providing an additional fast Fourier transformator.

Following the course frequency synchronization described above, a fine frequency synchronization can be performed in case such a fine frequency synchronization is useful.

CLAIMS

1. A method of performing a coarse frequency synchronization compensating for a carrier frequency deviation from an oscillator frequency in a demodulation system (130) capable of demodulating a signal having a frame structure comprising at least one useful symbol (162) and a reference symbol (166), said reference symbol (166) being an amplitude-modulated sequence, said method comprising the steps of:

receiving said signal;

down-converting said received signal;

performing an amplitude-demodulation of said down-converted signal in order to generate an envelope;

correlating said envelope with a predetermined reference pattern in order to determine said carrier frequency deviation; and

controlling said oscillator frequency based on said carrier frequency deviation.

2. The method of claim 1, wherein said carrier frequency deviation is determined as follows:

$$\Delta f = \frac{1}{2\pi T_{MCM}} \arg\left(\sum_{k=1}^{\frac{L}{2}} \tilde{r}(k) \cdot S_{AM}^{*} \right) \qquad \text{(Eq.6)}$$

wherein $\tilde{r}$ designates values of said portions;

S^{*}_{AM} designates the complex conjugate of the values of the identical sequences;

T_{MCM} designates the duration of said useful symbol;

k designates an index; and

L designates the number of values of said two sequences of said reference symbol.

3. A method of performing a coarse frequency synchronization compensation for a carrier frequency deviation from an oscillator frequency in a demodulation system (130) capable of demodulating a signal having a frame structure, said frame structure comprising at least one useful symbol (162) and a reference symbol (166), said reference symbol (166) being an amplitude-modulated sequence which comprises two identical sequences (300), said method comprising the steps of:

receiving said signal;

down-converting said received signal;

performing an amplitude-demodulation of the down-converted signal in order to generate an envelope, said envelope having two portions which are based on said identical sequences (300);

correlating one of said portions of said envelope with another one of said portions in order to determine said carrier frequency deviation; and

controlling said oscillator frequency based on said carrier frequency deviation.

4. The method of claim 3, wherein said correlating step further comprises weighting of corresponding values of said two portions with corresponding values of said two sequences.

5. The method of claim 3, wherein said carrier frequency deviation is determined as follows:

$$\Delta f = \frac{1}{2\pi \frac{L}{2} T_{MCM}} \arg\left(\sum_{k=1}^{\frac{L}{2}} \tilde{r}\left(k + \frac{L}{2}\right) \cdot \tilde{r}^{*}(k) \right) \qquad \text{(Eq.13)}$$

wherein $\tilde{r}$ designates values of said portions;

$\tilde{r}^{*}$ designates the complex conjugate of said values of said portions;

T_{MCM} designates the duration of said useful symbol;

k designates an index; and

L designates the number of values of said two sequences of said reference symbol.

6. The method of claim 4, wherein said carrier frequency deviation is determined as follows:

$$\Delta f = \frac{1}{2\pi \frac{L}{2} T_{MCM}} \arg\left(\sum_{k=1}^{\frac{L}{2}} \left[\tilde{r}\left(k + \frac{L}{2}\right) \cdot \tilde{r}^{*}(k) \right] \cdot \left[S_{AM}(k) S_{AM}^{*}\left(k + \frac{L}{2}\right) \right] \right) \qquad \text{(Eq.14)}$$

wherein $\tilde{r}$ designates values of said portions;

$\tilde{r}^{*}$ designates the complex conjugate of said values of said portions;

T_{MCM} designates the duration of said useful symbol;

k designates an index;

L designates the number of values of said two sequences of said reference symbol;

S_{AM} designates values of said identical sequences; and

S^*_{AM} designates the complex conjugate of said values of said identical sequences.

7. The method according one of claims 1 to 6, wherein said signal is an orthogonal frequency division multiplex signal.

8. The method according to one of claims 1 to 7, further comprising the step of performing a fast automatic gain control of said received down-converted signal prior to the step of performing said amplitude-demodulation.

9. The method according to one of claims 1 to 8, wherein the step of performing said amplitude-demodulation comprises the step of calculating an amplitude of said signal using the $alpha_{max+}$ $beta_{min-}$ method.

10. The method according to one of claims 1 to 9, further comprising the steps of sampling respective amplitudes of said received down-converted signal and comparing said sampled amplitudes with a predetermined threshold in order to generate a bit sequence in order to perform said amplitude-demodulation.

11. The method according to claim 10, wherein the step of sampling respective amplitudes of said received down-converted signal further comprises the step of performing an over-sampling of said received down-converted signal.

12. An apparatus for performing a coarse frequency synchronization compensating for a carrier frequency deviation from an oscillator frequency, for a demodulation system (130) capable of demodulating a signal having a frame structure, said frame structure comprising at least one useful symbol (162) and a reference symbol (166), said reference symbol being an amplitude-modulated sequence, said apparatus comprising:

receiving means (132) for receiving said signal;

a down-converter for down-converting said received signal;

an amplitude-demodulator for performing an amplitude-demodulation of said down-converted signal in order to generate an envelope;

a correlator for correlating said envelope with a predetermined reference pattern in order to determine said carrier frequency deviation; and

means for controlling said oscillator frequency based on said carrier frequency deviation.

13. The apparatus of claim 12, comprising means for determining said carrier frequency deviation as follows:

$$\Delta f = \frac{1}{2\pi T_{MCM}} \arg\left(\sum_{k=1}^{\frac{L}{2}} \tilde{r}(k) \cdot S_{AM}^{*} \right) \qquad \text{(Eq.6)}$$

wherein $\tilde{r}$ designates values of said portions;

S^{*}_{AM} designates the complex conjugate of the values of the identical sequences;

T_{MCM} designates the duration of said useful symbol;

k designates an index; and

L designates the number of values of said two sequences of said reference symbol.

14. An apparatus for performing a coarse frequency synchronization compensation for a carrier frequency deviation from an oscillator frequency, for a demodulation system (130) capable of demodulating a signal having a

frame structure, said frame structure comprising at least one useful symbol (162) and a reference symbol (166), said reference symbol (166) being an amplitude-modulated sequence which comprises two identical sequences (300), said apparatus comprising:

receiving means (132) for receiving said signal;

a down-converter for down-converting said received signal;

an amplitude-demodulator for performing an amplitude-demodulation of said down-converted signal in order to generate an envelope, said envelope having two portions which are based on said identical sequences (300);

a correlator for correlating one of said portions of said envelope with another one of said portions in order to determine said carrier frequency deviation; and

means for controlling said oscillator frequency based on said carrier frequency deviation.

15. The apparatus of claim 14, wherein said correlator comprises means for weighting of corresponding values of said two portions with corresponding values of said two sequences (300).

16. The apparatus of claim 13, comprising means for determining said carrier frequency deviation as follows:

$$\Delta f = \frac{1}{2\pi \frac{L}{2} T_{MCM}} \arg\left(\sum_{k=1}^{\frac{L}{2}} \tilde{r}\left(k + \frac{L}{2}\right) \cdot \tilde{r}^{*}(k) \right) \qquad \text{(Eq.13)}$$

wherein $\tilde{r}$ designates values of said portions;

$\tilde{r}^{*}$ designates the complex conjugate of said values of said portions;

T_{MCM} designates the duration of said useful symbol;

k designates an index; and

L designates the number of values of said two sequences of said reference symbol.

17. The apparatus of claim 15, comprising means for determining said carrier frequency deviation as follows:

$$\Delta f = \frac{1}{2\pi \frac{L}{2} T_{MCM}} \arg\left(\sum_{k=1}^{\frac{L}{2}} \left[\tilde{r}\left(k+\frac{L}{2}\right) \cdot \tilde{r}^{*}(k) \right] \cdot \left[S_{AM}(k) S_{AM}^{*}\left(k+\frac{L}{2}\right) \right] \right) \qquad \text{(Eq.14)}$$

wherein $\tilde{r}$ designates values of said portions;

$\tilde{r}^*$ designates the complex conjugate of said values of said portions;

T_{MCM} designates the duration of said useful symbol;

k designates an index;

L designates the number of values of said two sequences of said reference symbol;

S_{AM} designates values of said identical sequences; and

S^*_{AM} designates the complex conjugate of said values of said identical sequences.

18. The apparatus according to one of claims 13 to 17, wherein said signal is an orthogonal frequency division multiplexed signal.

19. The apparatus according to one of claims 13 to 18, further comprising means for performing a fast automatic

gain control of said received down-converted signal preceding said amplitude-demodulator.

20. The apparatus according to one of claims 13 to 18, wherein said amplitude-demodulator comprises means for calculating an amplitude of said signal using the $alpha_{max+}$ $beta_{min-}$ method.

21. The apparatus according to one of claims 13 to 20, further comprising means for sampling respective amplitudes of said received down-converted signal, wherein said amplitude-demodulator comprises means for comparing said sampled amplitudes with a predetermined threshold in order to generate a bit sequence.

22. The apparatus according to claim 21, wherein said means for sampling comprises means for over-sampling said received down-converted signal.

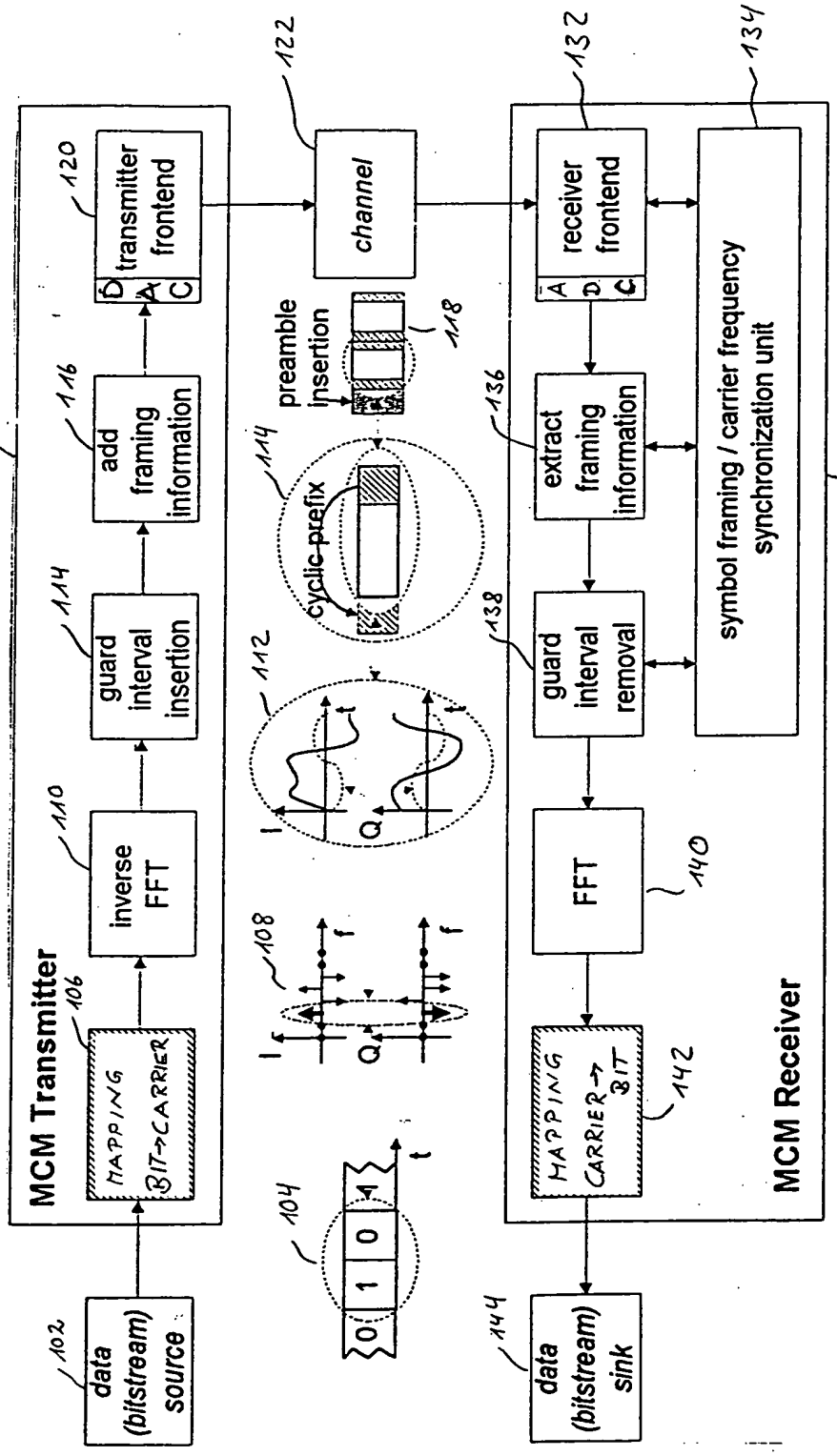
MCM Transmitter
MCM Receiver
data (bitstream) source
data (bitstream) sink
MAPPING BIT→CARRIER
CARRIER→BIT MAPPING
inverse FFT
FFT
guard interval insertion
guard interval removal
add framing information
extract framing information
preamble insertion
cyclic-prefix
transmitter frontend
receiver frontend
channel
symbol framing / carrier frequency synchronization unit
I
Q
f
t
0 1 0 1
100
102
104
106
108
110
112
114
116
118
120
122
130
132
134
136
138
140
142
144

Fig. 1

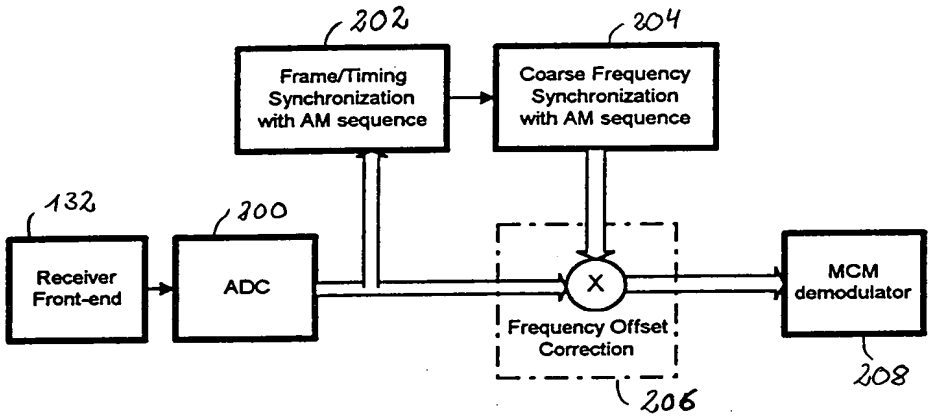
202
204
Frame/Timing Synchronization with AM sequence
Coarse Frequency Synchronization with AM sequence
132
200
Receiver Front-end
ADC
X
MCM demodulator
Frequency Offset Correction
206
208

Fig. 2

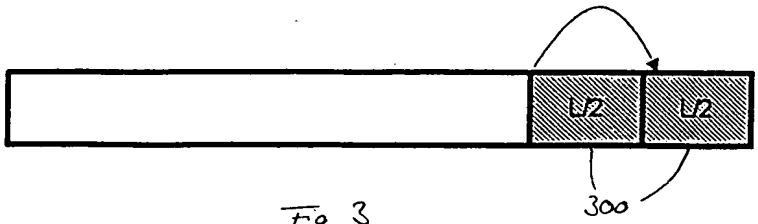

Fig 3

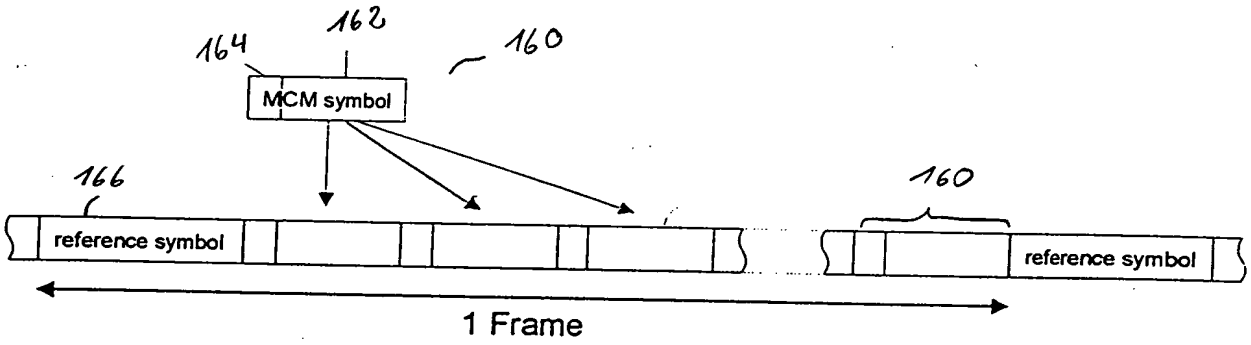

Fig. 4

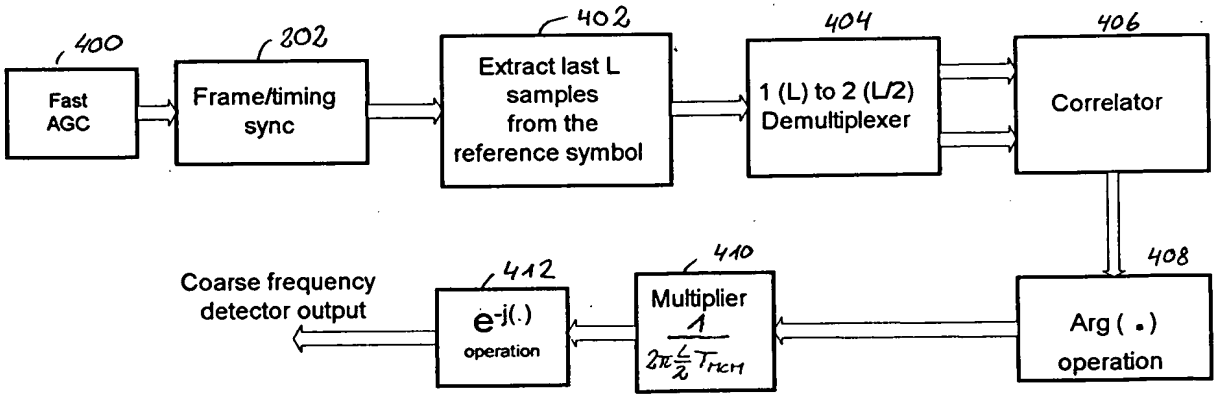

Fig. 5

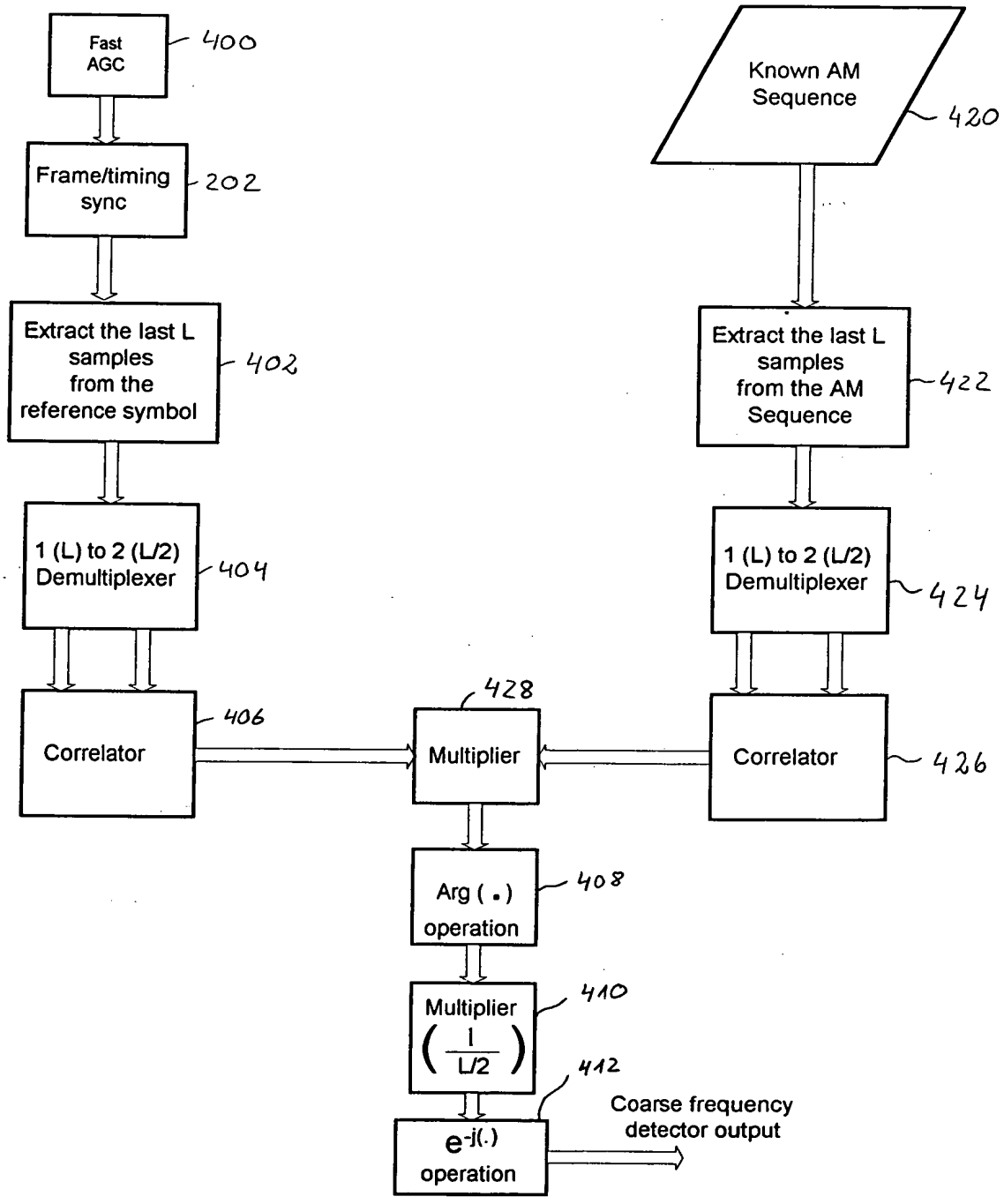
Fast AGC
400
Frame/timing sync
202
Extract the last L samples from the reference symbol
402
1 (L) to 2 (L/2) Demultiplexer
404
Correlator
406
Known AM Sequence
420
Extract the last L samples from the AM Sequence
422
1 (L) to 2 (L/2) Demultiplexer
424
Correlator
426
428
Multiplier
Arg (•) operation
408
Multiplier (1/L/2)
410
412
e-j(.) operation
Coarse frequency detector output

Fig. 6

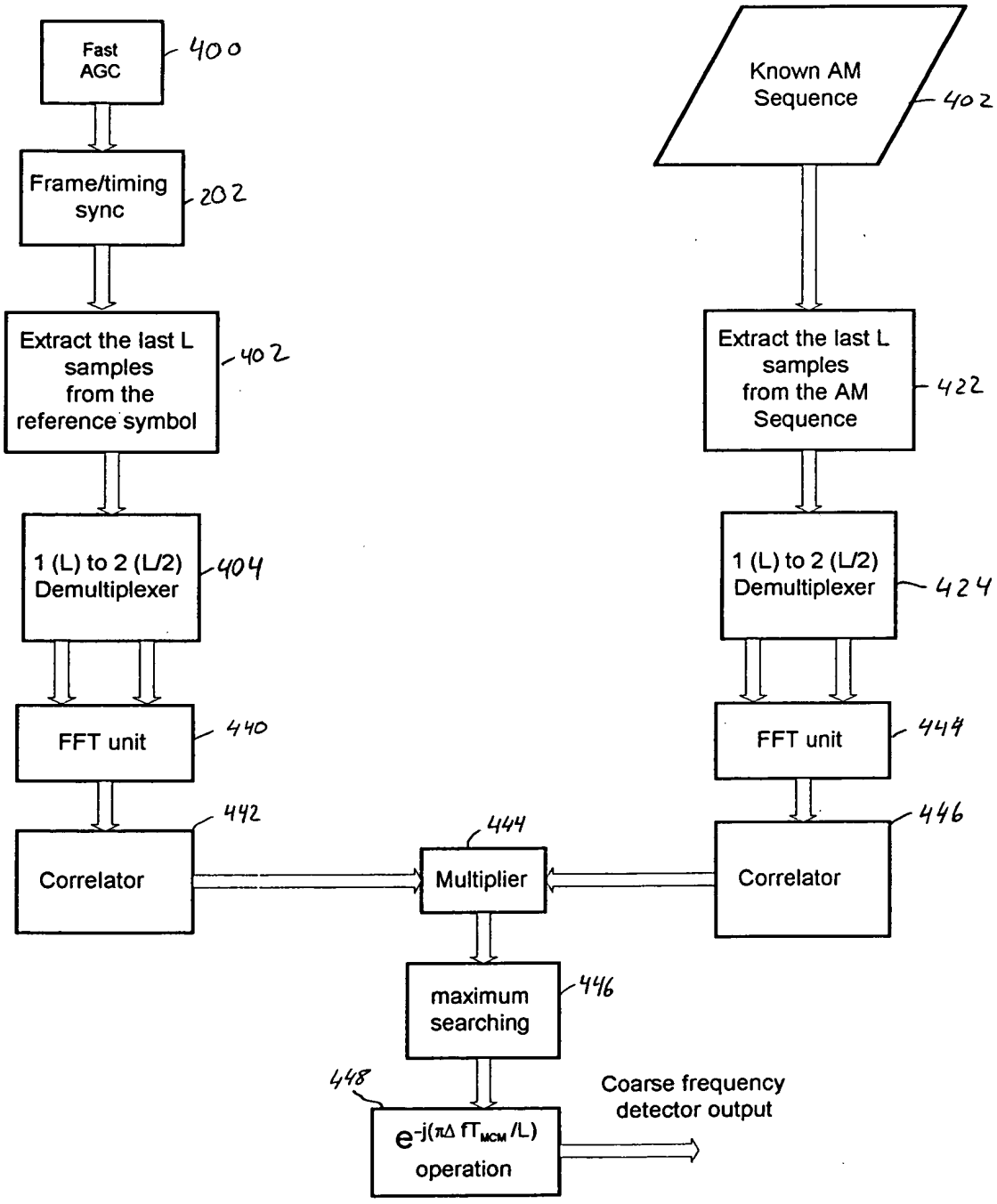
Fast AGC
400
Known AM Sequence
402
Frame/timing sync
202
Extract the last L samples from the reference symbol
402
Extract the last L samples from the AM Sequence
422
1 (L) to 2 (L/2) Demultiplexer
404
1 (L) to 2 (L/2) Demultiplexer
424
FFT unit
440
FFT unit
444
Correlator
442
Multiplier
444
Correlator
446
maximum searching
446
448
$e^{-j(\pi\Delta fT_{MCM}/L)}$ operation
Coarse frequency detector output

Fig. 7

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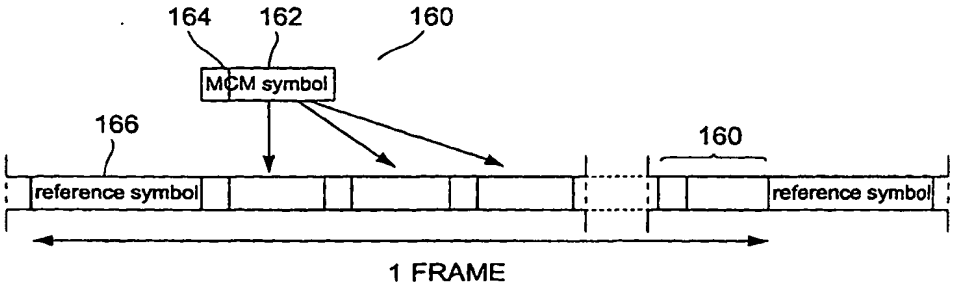

(57) Abstract

For performing a coarse frequency synchronization compensating for a carrier frequency deviation from an oscillator frequency in a demodulation system (130) capable of demodulating a signal having a frame structure, the frame structure comprising at least one useful symbol (162) and a reference symbol (166) which is an amplitude-modulated sequence, firstly the signal is received. Thereafter, the received signal is down-converted. Then, an amplitude-demodulation of the down-converted signal is performed in order to generate an envelope. This envelope is correlated with a predetermined reference pattern in order to determine the carrier frequency deviation. Finally, the oscillator frequency is controlled based on the carrier frequency deviation. The reference symbol may comprise two identical sequences (300). In this case, the envelope obtained by the amplitude-demodulation has two portions which are based on the identical sequences (300). One of the portions of the envelope is correlated with the other one of the portions in order to determine the carrier frequence deviation. The oscillator frequency is controlled based on the determined carrier frequency deviation.

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FRAME STRUCTURE AND FRAME SYNCHRONISATION FOR MULTICARRIER SYSTEMS

FIELD OF THE INVENTION

The present invention relates to methods and apparatus for performing a coarse frequency synchronization compensating for a carrier frequency deviation from an oscillator frequency in a demodulation system. In particular, the present invention relates to such methods and apparatus in a demodulation system for multi-carrier modulation signals, wherein the multi-carrier modulation (MCM) signals have a frame structure comprising at least one useful symbol and a reference symbol.

The present invention is particularly useful in a MCM transmission system using an orthogonal frequency division multiplexing (OFDM) for digital broadcasting.

BACKGROUND OF THE INVENTION

In a multi carrier transmission system (MCM, OFDM), the effect of a carrier frequency offset is substantially more considerable than in a single carrier transmission system. MCM is more sensitive to phase noise and frequency offset which occurs as amplitude distortion and inter carrier interference (ICI). The inter carrier interference has the effect that the subcarriers are no longer orthogonal in relation to each other. Frequency offsets occur after power on or also later due to frequency deviation of the oscillators used for downconversion into baseband. Typical accuracies for the frequency of a free running oscillator are about ±50 ppm of the carrier frequency. With a carrier frequency in the S-band of 2.34 Ghz, for example, there will be a maximum local oscillator (LO) frequency deviation of above 100 kHz (117.25 kHz). The above named effects result in high requirements on the algorithm used for frequency offset correction.

DESCRIPTION OF PRIOR ART

Most prior art algorithms for frequency synchronization divide frequency correction into two stages. In the first stage, a coarse synchronization is performed. In the second stage, a fine correction can be achieved. A frequently used algorithm for coarse synchronization of the carrier frequency uses a synchronization symbol which has a special spectral pattern in the frequency domain. Such a synchronization symbol is, for example, a CAZAC sequence (CAZAC = Constant Amplitude Zero Autocorrelation). Through comparison, i.e. the correlation, of the power spectrum of the received signal with that of the transmitted signal, the frequency carrier offset can be coarsely estimated. These prior art algorithms all work in the frequency domain. Reference is made, for example, to Ferdinand Claßen, Heinrich Meyr, "Synchronization Algorithms for an OFDM System for Mobile Communication", ITG-Fachtagung 130, Codierung für Quelle, Kanal und Übertragung, pp. 105 - 113, Oct. 26-28, 1994; and Timothy M. Schmidl, Donald C. Cox, "Low-Overhead, Low-Complexity [Burst] Synchronization for OFDM", in Proceedings of the IEEE International Conference on Communication ICC 1996, pp. 1301-1306 (1996).

For the coarse synchronization of the carrier frequency, Paul H. Moose, "A Technique for Orthogonal Frequency Division Multiplexing Frequency Offset Correction", IEEE Transaction On Communications, Vol. 42, No. 10, October 1994, suggest increasing the spacing between the subcarriers such that the subcarrier distance is greater than the maximum frequency difference between the received and transmitted carriers. The subcarrier distance is increased by reducing the number of sample values which are transformed by the Fast Fourier Transform. This corresponds to a reduction of the number of sampling values which are transformed by the Fast Fourier Transform.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide methods and apparatus for performing a coarse frequency synchronization even in the case of frequency offsets that correspond to a multiple of the subcarrier distance in a MCM signal.

In accordance with a first aspect, the present invention provides a method of performing a coarse frequency synchronization compensating for a carrier frequency deviation from an oscillator frequency in a demodulation system capable of demodulating a signal having a frame structure, said frame structure comprising at least one useful symbol and a reference symbol, said reference symbol being an amplitude-modulated sequence, the method comprising the steps of:

receiving the signal;

down-converting the received signal;

performing an amplitude-demodulation of the down-converted signal in order to generate an envelope;

correlating the envelope with a predetermined reference pattern in order to determine the carrier frequency deviation; and

controlling the oscillator frequency based on the carrier frequency deviation.

In accordance with a second aspect, the present invention provides a method of performing a coarse frequency synchronization compensating for a carrier frequency deviation from an oscillator frequency in a demodulation system capable of demodulating a signal having a frame structure, the frame structure comprising at least one useful symbol and a reference symbol, the reference symbol being an amplitude-

modulated sequence which comprises two identical sequences, the method comprising the steps of:

receiving the signal;

down-converting the received signal;

performing an amplitude-demodulation of the down-converted signal in order to generate an envelope, the envelope having two portions which are based on the identical sequences;

correlating one of the portions of the envelope with another one of the portions in order to determine the carrier frequency deviation; and

controlling the oscillator frequency based on the carrier frequency deviation.

In accordance with a third aspect, the present invention provides an apparatus for performing a coarse frequency synchronization compensating for a carrier frequency deviation from an oscillator frequency, for a demodulation system capable of demodulating a signal having a frame structure, the frame structure comprising at least one useful symbol and a reference symbol, the reference symbol being an amplitude-modulated sequence, the apparatus comprising:

receiving means for receiving the signal;

a down-converter for down-converting the received signal;

an amplitude-demodulator for performing an amplitude-demodulation of the down-converted signal in order to generate an envelope;

a correlator for correlating the envelope with a predetermined reference pattern in order to determine the carrier

frequency deviation; and

means for controlling the oscillator frequency based on the carrier frequency deviation.

In accordance with a fourth aspect, the present invention provides an apparatus for performing a coarse frequency synchronization compensating for a carrier frequency deviation from an oscillator frequency, for a demodulation system capable of demodulating a signal having a frame structure, the frame structure comprising at least one useful symbol and a reference symbol, the reference symbol being an amplitude-modulated sequence which comprises two identical sequences, the apparatus comprising:

receiving means for receiving the signal;

a down-converter for down-converting the received signal;

an amplitude-demodulator for performing an amplitude-demodulation of the down-converted signal in order to generate an envelope, the envelope having two portions which are based on the identical sequences;

a correlator for correlating one of the portions of the envelope with another one of the portions in order to determine the carrier frequency deviation; and

means for controlling the oscillator frequency based on the carrier frequency deviation.

The present invention provides a new scheme for a coarse frequency synchronization, in particular in MCM systems. The present invention is particularly useful in systems which use a differential coding and mapping along the frequency axis. In accordance with the present invention, the algorithm for the coarse frequency synchronization is based on a reference symbol which is formed by an amplitude-modulated

sequence. The length of this amplitude-modulated sequence symbol may be less than that of the useful symbol. The algorithm in accordance with the present invention can be used in the time domain or the frequency domain. In order to determine a frequency offset, a correlation of the received MCM symbol with a predetermined reference pattern is performed in accordance with a first embodiment of the present invention. In accordance with a second embodiment of the present invention, the reference symbol comprises at least two identical amplitude-modulated sequences, wherein a frequency offset is determined based on a correlation between demodulated portions corresponding to these identical sequences.

It is preferred to select the mean amplitude of the reference symbol identically to the mean amplitude of the rest of the signal, i.e. to select all of the samples of the demodulated amplitude-modulated sequence in the middle of their amplitude range. Care has to be taken that the time constant of an automatic gain control (AGC) is selected to be long enough that the strong signal part of the reference symbol does not excessively influence the automatic gain control signal. Otherwise, the signal occuring after the amplitude-modulated sequence would be strongly attenuated.

According to preferred embodiments of the present invention, the amplitude-modulated sequence of the reference symbol is chosen to be a pseudo random bit sequence (PRBS) since such a sequence has good autocorrelation properties with a distinct correlation maximum in a correlation signal which should be as wide as possible.

In accordance with preferred embodiments of the present invention, the coarse frequency synchronization can be performed using the amplitude-modulated sequence after a frame synchronization of a MCM signal has been accomplished. The inventive algorithm works both in the time and the frequency domains. Frequency offsets as high as ±10 times

the subcarrier spacing can be corrected.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following, preferred embodiments of the present invention will be explained in detail on the basis of the drawings enclosed, in which:

Figure 1 shows a schematic overview of a MCM transmission system comprising a coarse frequency synchronization unit in accordance with the present invention;

Figure 2 shows a schematic block diagram for illustrating the coarse frequency synchronization in accordance with the present invention;

Figure 3 shows a schematic view of a reference symbol comprising two identical sequences;

Figure 4 shows a schematic view of a typical MCM signal having a frame structure;

Figure 5 shows a block diagram of an embodiment of a coarse frequency synchronization unit;

Figure 6 shows a block diagram of another embodiment of a coarse frequency synchronization unit; and

Figure 7 shows a block diagram of still another embodiment of a coarse frequency synchronization unit.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Before discussing the present invention in detail, the mode of operation of a MCM transmission system is described referring to Figure 1. Although the present invention is

explained referring to a MCM system as shown in Figure 1, it is clear that the present invention can be used in connection with different signal transmissions as long as the transmitted signal comprises useful symbols and reference symbols.

Referring to Figure 1, at 100 a MCM transmitter is shown that substantially corresponds to a prior art MCM transmitter. A description of such a MCM transmitter can be found, for example, in William Y. Zou, Yiyan Wu, "COFDM: AN OVERVIEW", IEEE Transactions on Broadcasting, vol. 41, No. 1, March 1995.

A data source 102 provides a serial bitstream 104 to the MCM transmitter. The incoming serial bitstream 104 is applied to a bit-carrier mapper 106 which produces a sequence of spectra 108 from the incoming serial bitstream 104. An inverse fast Fourier transform (IFFT) 110 is performed on the sequence of spectra 108 in order to produce a MCM time domain signal 112. The MCM time domain signal forms the useful MCM symbol of the MCM time signal. To avoid inter-symbol interference (ISI) caused by multipath distortion, a unit 114 is provided for inserting a guard interval of fixed length between adjacent MCM symbols in time. In accordance with a preferred embodiment of the present invention, the last part of the useful MCM symbol is used as the guard interval by placing same in front of the useful symbol. The resulting MCM symbol is shown at 115 in Figure 1 and corresponds to a MCM symbol 160 depicted in Figure 4.

Figure 4 shows the construction of a typical MCM signal having a frame structure. One frame of the MCM time signal is composed of a plurality of MCM symbols 160. Each MCM symbol 160 is formed by an useful symbol 162 and a guard interval 164 associated therewith. As shown in Figure 4, each frame comprises one reference symbol 166. The present invention can advantageously be used with such a MCM signal, however, such a signal structure being not necessary for

performing the present invention as long as the transmitted signal comprises a useful portion and at least one reference symbol.

In order to obtain the final frame structure shown in Figure 4, a unit 116 for adding a reference symbol for each predetermined number of MCM symbols is provided.

In accordance with the present invention, the reference symbol is an amplitude modulated bit sequence. Thus, an amplitude modulation of a bit sequence is performed such that the envelope of the amplitude modulated bit sequence defines a reference pattern of the reference symbol. This reference pattern defined by the envelope of the amplitude modulated bit sequence has to be detected when receiving the MCM signal at a MCM receiver. In a preferred embodiment of the present invention, a pseudo random bit sequence having good autocorrelation properties is used as the bit sequence for the amplitude modulation.

The choice of length and repetition rate of the reference symbol depends on the properties of the channel through which the MCM signal is transmitted, e.g. the coherence time of the channel. In addition, the repetition rate and the length of the reference symbol, in other words the number of useful symbols in each frame, depends on the receiver requirements concerning mean time for initial synchronization and mean time for resynchronization after synchronization loss due to a channel fade.

The resulting MCM signal having the structure shown at 118 in Figure 1 is applied to the transmitter front end 120. Roughly spoken, at the transmitter front end 120, a digital/analog conversion and an up-converting of the MCM signal is performed. Thereafter, the MCM signal is transmitted through a channel 122.

Following, the mode of operation of a MCM receiver 130 is

shortly described referring to Figure 1. The MCM signal is received at the receiver front end 132. In the receiver front end 132, the MCM signal is down-converted and, furthermore, a analog/digital conversion of the down-converted signal is performed.

The down-converted MCM signal is provided to a symbol frame/carrier frequency synchronization unit 134.

A first object of the symbol frame/carrier frequency synchronization unit is to perform a frame synchronization on the basis of the amplitude-modulated reference symbol. This frame synchronization is performed on the basis of a correlation between the amplitude-demodulated reference symbol an a predetermined reference pattern stored in the MCM receiver.

A second object of the symbol frame/carrier frequency synchronization unit is to perform a coarse frequency synchronization of the MCM signal. To this end, the symbol frame/carrier frequency synchronization unit 134 serves as a coarse frequency synchronization unit for determining a coarse frequency offset of the carrier frequence caused, for example, by a difference of the frequencies between the local oscillator of the transmitter and the local oscillator of the receiver. The determined frequency is used in order to perform a coarse frequency correction. The mode of operation of the coarse frequency synchronization unit is described in detail referring to Figures 2 and 3 hereinafter.

As described above, the frame synchronization unit 134 determines the location of the reference symbol in the MCM signal. Based on the determination of the frame synchronization unit 134, a reference symbol extracting unit 136 extracts the framing information, i.e. the reference symbol, from the MCM signal coming from the receiver front end 132. After the extraction of the reference symbol, the MCM signal

is applied to a guard interval removal unit 138. The result of the signal processing performed hereherto in the MCM receiver are the useful MCM symbols.

The useful MCM symbols output from the guard interval removal unit 138 are provided to a fast Fourier transform unit 140 in order to provide a sequence of spectra from the useful symbols. Thereafter, the sequence of spectra is provided to a carrier-bit mapper 142 in which the serial bitstream is recovered. This serial bitstream is provided to a data sink 144.

Following, the mode of operation of the coarse frequency synchronization unit will be described in detail referring to Figures 2 and 3. As it is shown in Figure 2, the output of the receiver front end 132 is connected to an analog/digital converter 200. The down-converted MCM signal is sampled at the output of the analog/digital converter 200 and is applied to a frame/timing synchronization unit 202. In a preferred embodiment, a fast running automatic gain control (AGC) (not shown) is provided preceding the frame/timing synchronization unit in order to eliminate fast channel fluctuations. The fast AGC is used in addition to the normally slow AGC in the signal path, in the case of transmission over a multipath channel with long channel impulse response and frequency selective fading. The fast AGC adjusts the average amplitude range of the signal to the known average amplitude of the reference symbol.

As described above, the frame/timing synchronization unit uses the amplitude-modulated sequence in the received signal in order to extract the framing information from the MCM signal and further to remove the guard intervals therefrom. After the frame/timing synchronization unit 202 it follows a coarse frequency synchronization unit 204 which estimates a coarse frequency offset based on the amplitude-modulated sequence of the reference symbol of the MCM signal. In the coarse frequency synchronization unit 204, a frequency

offset of the carrier frequency with respect to the oscillator frequency in the MCM receiver is determined in oder to perform a frequency offset correction in a block 206. This frequency offset correction in block 206 is performed by a complex multiplication. The output of the frequency offset correction block 206 is applied to the MCM demodulator 208 formed by the Fast Fourier Transformator 140 and the carrier-bit mapper 142 shown in Figure 1.

In order to perform the inventive coarse frequency synchronization, in either case, an amplitude-demodulation has to be performed on a preprocessed MCM signal. The preprocessing may be, for example, the down-conversion and the analog/digital conversion of the MCM signal. The result of the amplitude-demodulation of the preprocessed MCM signal is an envelope representing the amplitude of the MCM signal.

For the amplitude demodulation a simple $\text{alpha}_{\text{max+}}$ $\text{beta}_{\text{min-}}$ method can be used. This method is described for example in Palachels A.: DSP-mP Routine Computes Magnitude, EDN, October 26, 1989; and Adams, W. T., and Bradley, J.: Magnitude Approximations for Microprocessor Implementation, IEEE Micro, Vol. 3, No. 5, October 1983.

It is clear that amplitude determining methods different from the described $\text{alpha}_{\text{max+}}$ $\text{beta}_{\text{min-}}$ method can be used. For simplification, it is possible to reduce the amplitude calculation to a detection as to whether the current amplitude is above or below the average amplitude. The output signal then consists of a -1/+1 sequence which can be used to determine a coarse frequency offset by performing a correlation. This correlation can easily be performed using a simple integrated circuit (IC).

In addition, an oversampling of the signal received at the RF front end can be performed. For example, the received signal can be expressed with two times oversampling.

In accordance with a first embodiment of the present invention, a carrier frequency offset of the MCM signal from an oscillator frequency in the MCM receiver is determined by correlating the envelope obtained by performing the amplitude-demodulation as described above with a predetermined reference pattern.

In case there is no frequency offset, the received reference symbol r(k) will be:

$$r(k) = S_{AM}(k) + n(k) \qquad \text{(Eq.1)}$$

wherein n(k) designates "additive Gaussian noise" and S_{AM} denotes the AM sequence which has been sent. In order to simplify the calculation the additive Gaussian noise can be neglected. It follows:

$$r(k) \cong S_{AM}(k) \qquad \text{(Eq.2)}$$

In case a constant frequency offset Δf is present, the received signal will be:

$$\tilde{r}(k) = S_{AM}(k) \cdot e^{j2\pi\Delta f k T_{MCM}} \qquad \text{(Eq.3)}$$

Information regarding the frequency offset is derived from the correlation of the received signal r(k) with the AM sequence S_{AM} which is known in the receiver:

$$\sum_{k=1}^{\frac{L}{2}} \tilde{r}(k) \cdot S_{AM}^{*}(k) = \sum_{k=1}^{\frac{L}{2}} \left| S_{AM}(k) \right|^2 e^{j2\pi\Delta f k T_{MCM}} \qquad \text{(Eq.4)}$$

Thus, the frequency offset is:

$$\Delta f = \frac{1}{2\pi T_{MCM}} \arg\left(\sum_{k=1}^{\frac{L}{2}} r(k) \cdot S_{AM}^{*}(k) \right) - \frac{1}{2\pi T_{MCM}} \arg\left(\sum_{k=1}^{\frac{L}{2}} \left| S_{AM}(k) \right|^2 \right) \qquad \text{(Eq.5)}$$

Since the argument of $|S_{AM}(k)|^2$ is zero the frequency offset is:

$$\Delta f = \frac{1}{2\pi T_{MCM}} \arg\left(\sum_{k=1}^{\frac{L}{2}} \tilde{r}(k) \cdot S_{AM}^{*} \right) \qquad \text{(Eq.6)}$$

In accordance with a second embodiment of the coarse frequency synchronization algorithm in accordance with the present invention, a reference symbol comprising at least two identical sequences 300 as shown in Figure 3 is used. Figure 3 shows the reference symbol of a MCM signal having two identical sequences 300 of a length of L/2 each. L designates the number of values of the two sequences 300 of the reference symbol.

As shown in Figure 3, within the amplitude-modulated sequence, there are at least two identical sections devoted to the coarse frequency synchronization. Two such sections, each containing L/2 samples, are shown at the end of the amplitude-modulated sequence in Figure 3. The amplitude-modulated sequence contains a large number of samples. For a non-ambiguous observation of the phase, only enough samples to contain a phase rotation of 2π should be used. This number is defined as L/2 in Figure 3.

Following, a mathematical derivation of the determination of a carrier frequency deviation is presented. In accordance with Figure 3, the following equation applies for the two identical sequences 300:

$$s\left(0 < k \le \frac{L}{2}\right) \equiv s\left(\frac{L}{2} < k \le L\right) \qquad \text{(Eq.7)}$$

If no frequency offset is present, the following equation 8 will be met by the received signal:

$$r\left(k + \frac{L}{2}\right) \equiv r(k) \qquad 0 < k \le \frac{L}{2} \qquad \text{(Eq.8)}$$

r(k) designates the values of the identical sequences. k is an index from one to L/2 for the respective samples.

If there is a frequency offset of, for example, Δf, the received signal is:

$$\tilde{r}(k) = r(k) \cdot e^{j2\pi\Delta f k T_{MCM}} \qquad \text{(Eq.9)}$$

$$\tilde{r}(k+\frac{L}{2}) = r(k) \cdot e^{j2\pi\Delta f\left(k+\frac{L}{2}\right)T_{MCM}} \qquad \text{(Eq.10)}$$

$\tilde{r}(k)$ designates sample values of the received portion which are based on the identical sequences. Information regarding the frequency offset is derived from the correlation of the received signal $\tilde{r}(k+L/2)$ with the received signal $\tilde{r}(k)$. This correlation is given by the following equation:

$$\sum_{k=1}^{\frac{L}{2}} \tilde{r}^{*}\left(k+\frac{L}{2}\right)\tilde{r}(k) = \sum_{k=1}^{\frac{L}{2}} |r(k)|^2 e^{-j2\pi\Delta f \frac{L}{2} T_{MCM}} \qquad \text{(Eq.11)}$$

$\tilde{r}^*$ designates the complex conjugate of the sample values of the portion mentioned above.

Thus, the frequency offset is

$$\Delta f = \frac{1}{2\pi\frac{L}{2}T_{MCM}} \arg\left(\sum_{k=1}^{\frac{L}{2}} \tilde{r}\left(k+\frac{L}{2}\right)\cdot\tilde{r}^{*}(k)\right) - \frac{1}{2\pi\frac{L}{2}T_{MCM}} \arg\left(\sum_{k=1}^{\frac{L}{2}} |\tilde{r}(k)|^2\right) \qquad \text{(Eq.12)}$$

Since the argument of $|r(k)|^2$ equals zero, the frequency offset becomes

$$\Delta f = \frac{1}{2\pi\frac{L}{2}T_{MCM}} \arg\left(\sum_{k=1}^{\frac{L}{2}} \tilde{r}\left(k+\frac{L}{2}\right)\cdot\tilde{r}^{*}(k)\right) \qquad \text{(Eq.13)}$$

Thus, it is clear that in both embodiments, described above, the frequency position of the maximum of the resulting output of the correlation determines the estimated value of the offset carrier. Furthermore, as it is also shown in Figure 2, the correction is performed in a feed forward structure.

An apparatus for performing the coarse frequency

synchronization using a reference symbol having two identical sections of the length of L/2 each which has been described above is shown in Figure 5.

Also shown in Figure 5 is the frame/timing synchronization unit 202. As can be seen from Figure 5, a unit 400 for performing a fast automatic gain control (time constant < MCM symbol duration) can be provided preceding the frame/timing synchronization unit. The output of the frame/timing synchronization unit 202 is connected to an extracting unit 402 which is operable to extract the last L samples from the reference symbol. The output of the extracting unit 402 is connected to a demultiplexer 404 which recovers the two identical sections having the length of L/2 each from the L samples. The identical sections are applied to a correlator 406 which performs the correlation as described above.

The output of the correlator 406 is connected to an operation unit 408 for performing an argument operation on the output signal of the correlator 406. The output of the operation unit 408 is connected to a multiplier 410 which multiplies the output by $1/(2\pi(L/2)T_{MCM})$. A further operation unit 412 for performing a $e^{-j(\pi\Delta f T_{MCM}/L)}$ operation is provided in order to derive the frequency shift for the whole MCM symbol from the frequency shift determined for the portion having the length of L, i.e. the identical sections 300 shown in Figure 3.

In case of a channel with strong reflections, for example due to a high building density, the correlations described above might be insufficient for obtaining a suitable coarse frequency synchronization. Therefore, in accordance with a third embodiment of the present invention, corresponding values of the two portions which are correlated in accordance with a second embodiment, can be weighting with corresponding values of stored predetermined reference patterns corresponding to said two identical sequences of

the reference symbol. This weighting can maximize the probability of correctly determining the frequency offset. The mathematical description of this weighting is as follows:

$$\Delta f = \frac{1}{2\pi \frac{L}{2} T_{MCM}} \arg\left(\sum_{k=1}^{\frac{L}{2}} \left[\tilde{r}\left(k + \frac{L}{2}\right) \cdot \tilde{r}^{*}(k) \right] \cdot \left[S_{AM}(k) S_{AM}^{*}\left(k + \frac{L}{2}\right) \right] \right) \qquad \text{(Eq.14)}$$

S_{AM} designates the amplitude-modulated sequence which is known in the receiver, and S^{*}_{AM} designates the complex conjugate thereof.

If the above correlations are calculated in the frequency domain, the amount of

$$\sum_{k=1}^{\frac{L}{2}} \left[\tilde{r}\left(k + \frac{L}{2}\right) \cdot \tilde{r}^{*}(k) \right] \cdot \left[S_{AM}(k) S_{AM}^{*}\left(k + \frac{L}{2}\right) \right] \qquad \text{(Eq.15)}$$

is used rather than the argument. This amount is maximized as a function of a frequency correction. The position of the maximum determines the estimation of the frequency deviation. As mentioned above, the correction is performed in a feed forward structure.

A block diagram of an apparatus for performing the coarse frequency synchronization in accordance with the third embodiment of the present invention is shown in Figure 6.

Blocks 400, 202, 402, 404 and 406 shown in the left branch of Figure 6 correspond to the respective blocks in Figure 5. In the right branch of Figure 6, the preparation of the known AM sequence is shown. The known AM sequence is read from a memory 420 and applied to an extracting unit 422 which extracts the last L samples therefrom. The output of the extracting unit 422 is connected to a demultiplexer 424 having one input and two outputs in order to recover the identical sections having a length of L/2 each. Both outputs of the demultiplexer are connected with a correlator 426 which performs a correlation between the two identical

sections.

A multiplier 428 is provided which multiplies the output of the correlator 406 by the output of the correlator 426. The output of the multiplier 425 is connected to an argument operation unit 408. The output of the multiplier is applied to an argument operation unit 408, a multiplier 410 and an operation unit 412 in sequence. The mode of operation of these units corresponds to that of the corresponding units which are shown in Figure 5.

A alternative structure of an apparatus for performing the coarse frequency synchronization in accordance with the third embodiment of the present invention in the frequency domain is shown in Figure 7. As shown in Figure 7, a fast Fourier transformator 440 is provided between the demultiplexer 404 and a correlator 442, and a fast Fourier transformator 444 is provided between the demultiplexer 424 and a correlator 426. The outputs of the correlators 442 and 446 are connected to a multiplier 444. The output of the multiplier 444 is connected to a maximum searching unit 446. Finally, a unit 448 for performing a $e^{-j(\pi\Delta f T_{MCM}/L)}$ operation is provided. The output of this unit 448 represents the output of the coarse frequency synchronization device.

In case of performing the coarse frequency synchronization in the frequency domain it is possible to make use of the existing FFT at the beginning of the detection for the coarse frequency synchronization rather than providing an additional fast Fourier transformator.

Following the course frequency synchronization described above, a fine frequency synchronization can be performed in case such a fine frequency synchronization is useful.

CLAIMS

1. A method of performing a coarse frequency synchronization compensating for a carrier frequency deviation from an oscillator frequency in a demodulation system (130) capable of demodulating a signal having a frame structure comprising at least one useful symbol (162) and a reference symbol (166), said reference symbol (166) being an amplitude-modulated sequence, said method comprising the steps of:

receiving said signal;

down-converting said received signal;

performing an amplitude-demodulation of said down-converted signal in order to generate an envelope;

correlating said envelope with a predetermined reference pattern in order to determine said carrier frequency deviation; and

controlling said oscillator frequency based on said carrier frequency deviation.

2. The method of claim 1, wherein said carrier frequency deviation is determined as follows:

$$\Delta f = \frac{1}{2\pi T_{MCM}} \arg\left(\sum_{k=1}^{\frac{L}{2}} \tilde{r}(k) \cdot S_{AM}^{*} \right) \qquad \text{(Eq.6)}$$

wherein $\tilde{r}$ designates values of said portions;

S^{*}_{AM} designates the complex conjugate of the values of the identical sequences;

T_{MCM} designates the duration of said useful symbol;

k designates an index; and

L designates the number of values of said two sequences of said reference symbol.

3. A method of performing a coarse frequency synchronization compensation for a carrier frequency deviation from an oscillator frequency in a demodulation system (130) capable of demodulating a signal having a frame structure, said frame structure comprising at least one useful symbol (162) and a reference symbol (166), said reference symbol (166) being an amplitude-modulated sequence which comprises two identical sequences (300), said method comprising the steps of:

receiving said signal;

down-converting said received signal;

performing an amplitude-demodulation of the down-converted signal in order to generate an envelope, said envelope having two portions which are based on said identical sequences (300);

correlating one of said portions of said envelope with another one of said portions in order to determine said carrier frequency deviation; and

controlling said oscillator frequency based on said carrier frequency deviation.

4. The method of claim 3, wherein said correlating step further comprises weighting of corresponding values of said two portions with corresponding values of said two sequences.

5. The method of claim 3, wherein said carrier frequency deviation is determined as follows:

$$\Delta f = \frac{1}{2\pi \frac{L}{2} T_{MCM}} \arg\left(\sum_{k=1}^{\frac{L}{2}} \tilde{r}\left(k + \frac{L}{2}\right) \cdot \tilde{r}^{*}(k) \right) \qquad \text{(Eq.13)}$$

wherein $\tilde{r}$ designates values of said portions;

$\tilde{r}^{*}$ designates the complex conjugate of said values of said portions;

T_{MCM} designates the duration of said useful symbol;

k designates an index; and

L designates the number of values of said two sequences of said reference symbol.

6. The method of claim 4, wherein said carrier frequency deviation is determined as follows:

$$\Delta f = \frac{1}{2\pi \frac{L}{2} T_{MCM}} \arg\left(\sum_{k=1}^{\frac{L}{2}} \left[\tilde{r}\left(k + \frac{L}{2}\right) \cdot \tilde{r}^{*}(k) \right] \cdot \left[S_{AM}(k) S_{AM}^{*}\left(k + \frac{L}{2}\right) \right] \right) \qquad \text{(Eq.14)}$$

wherein $\tilde{r}$ designates values of said portions;

$\tilde{r}^{*}$ designates the complex conjugate of said values of said portions;

T_{MCM} designates the duration of said useful symbol;

k designates an index;

L designates the number of values of said two sequences of said reference symbol;

S_{AM} designates values of said identical sequences; and

S^*_{AM} designates the complex conjugate of said values of said identical sequences.

7. The method according one of claims 1 to 6, wherein said signal is an orthogonal frequency division multiplex signal.

8. The method according to one of claims 1 to 7, further comprising the step of performing a fast automatic gain control of said received down-converted signal prior to the step of performing said amplitude-demodulation.

9. The method according to one of claims 1 to 8, wherein the step of performing said amplitude-demodulation comprises the step of calculating an amplitude of said signal using the $alpha_{max+}$ $beta_{min-}$ method.

10. The method according to one of claims 1 to 9, further comprising the steps of sampling respective amplitudes of said received down-converted signal and comparing said sampled amplitudes with a predetermined threshold in order to generate a bit sequence in order to perform said amplitude-demodulation.

11. The method according to claim 10, wherein the step of sampling respective amplitudes of said received down-converted signal further comprises the step of performing an over-sampling of said received down-converted signal.

12. An apparatus for performing a coarse frequency synchronization compensating for a carrier frequency deviation from an oscillator frequency, for a demodulation system (130) capable of demodulating a signal having a frame structure, said frame structure comprising at least one useful symbol (162) and a reference symbol (166), said reference symbol being an amplitude-modulated sequence, said apparatus comprising:

receiving means (132) for receiving said signal;

a down-converter for down-converting said received signal;

an amplitude-demodulator for performing an amplitude-demodulation of said down-converted signal in order to generate an envelope;

a correlator for correlating said envelope with a predetermined reference pattern in order to determine said carrier frequency deviation; and

means for controlling said oscillator frequency based on said carrier frequency deviation.

13. The apparatus of claim 12, comprising means for determining said carrier frequency deviation as follows:

$$\Delta f = \frac{1}{2\pi T_{MCM}} \arg\left(\sum_{k=1}^{\frac{L}{2}} \tilde{r}(k) \cdot S^{*}_{AM} \right) \qquad \text{(Eq.6)}$$

wherein $\tilde{r}$ designates values of said portions;

S^{*}_{AM} designates the complex conjugate of the values of the identical sequences;

T_{MCM} designates the duration of said useful symbol;

k designates an index; and

L designates the number of values of said two sequences of said reference symbol.

14. An apparatus for performing a coarse frequency synchronization compensation for a carrier frequency deviation from an oscillator frequency, for a demodulation system (130) capable of demodulating a signal having a

frame structure, said frame structure comprising at least one useful symbol (162) and a reference symbol (166), said reference symbol (166) being an amplitude-modulated sequence which comprises two identical sequences (300), said apparatus comprising:

receiving means (132) for receiving said signal;

a down-converter for down-converting said received signal;

an amplitude-demodulator for performing an amplitude-demodulation of said down-converted signal in order to generate an envelope, said envelope having two portions which are based on said identical sequences (300);

a correlator for correlating one of said portions of said envelope with another one of said portions in order to determine said carrier frequency deviation; and

means for controlling said oscillator frequency based on said carrier frequency deviation.

15. The apparatus of claim 14, wherein said correlator comprises means for weighting of corresponding values of said two portions with corresponding values of said two sequences (300).

16. The apparatus of claim 13, comprising means for determining said carrier frequency deviation as follows:

$$\Delta f = \frac{1}{2\pi \frac{L}{2} T_{MCM}} \arg\left(\sum_{k=1}^{\frac{L}{2}} \tilde{r}\left(k + \frac{L}{2}\right) \cdot \tilde{r}^{*}(k) \right) \qquad \text{(Eq.13)}$$

wherein $\tilde{r}$ designates values of said portions;

$\tilde{r}^{*}$ designates the complex conjugate of said values of said portions;

T_{MCM} designates the duration of said useful symbol;

k designates an index; and

L designates the number of values of said two sequences of said reference symbol.

17. The apparatus of claim 15, comprising means for determining said carrier frequency deviation as follows:

$$\Delta f = \frac{1}{2\pi \frac{L}{2} T_{MCM}} \arg\left(\sum_{k=1}^{\frac{L}{2}} \left[\tilde{r}\left(k + \frac{L}{2}\right) \cdot \tilde{r}^{*}(k) \right] \cdot \left[S_{AM}(k) S_{AM}^{*}\left(k + \frac{L}{2}\right) \right] \right) \qquad \text{(Eq.14)}$$

wherein $\tilde{r}$ designates values of said portions;

$\tilde{r}^{*}$ designates the complex conjugate of said values of said portions;

T_{MCM} designates the duration of said useful symbol;

k designates an index;

L designates the number of values of said two sequences of said reference symbol;

S_{AM} designates values of said identical sequences; and

S^{*}_{AM} designates the complex conjugate of said values of said identical sequences.

18. The apparatus according to one of claims 13 to 17, wherein said signal is an orthogonal frequency division multiplexed signal.

19. The apparatus according to one of claims 13 to 18, further comprising means for performing a fast automatic

gain control of said received down-converted signal preceding said amplitude-demodulator.

20. The apparatus according to one of claims 13 to 18, wherein said amplitude-demodulator comprises means for calculating an amplitude of said signal using the $alpha_{max+}$ $beta_{min-}$ method.

21. The apparatus according to one of claims 13 to 20, further comprising means for sampling respective amplitudes of said received down-converted signal, wherein said amplitude-demodulator comprises means for comparing said sampled amplitudes with a predetermined threshold in order to generate a bit sequence.

22. The apparatus according to claim 21, wherein said means for sampling comprises means for over-sampling said received down-converted signal.

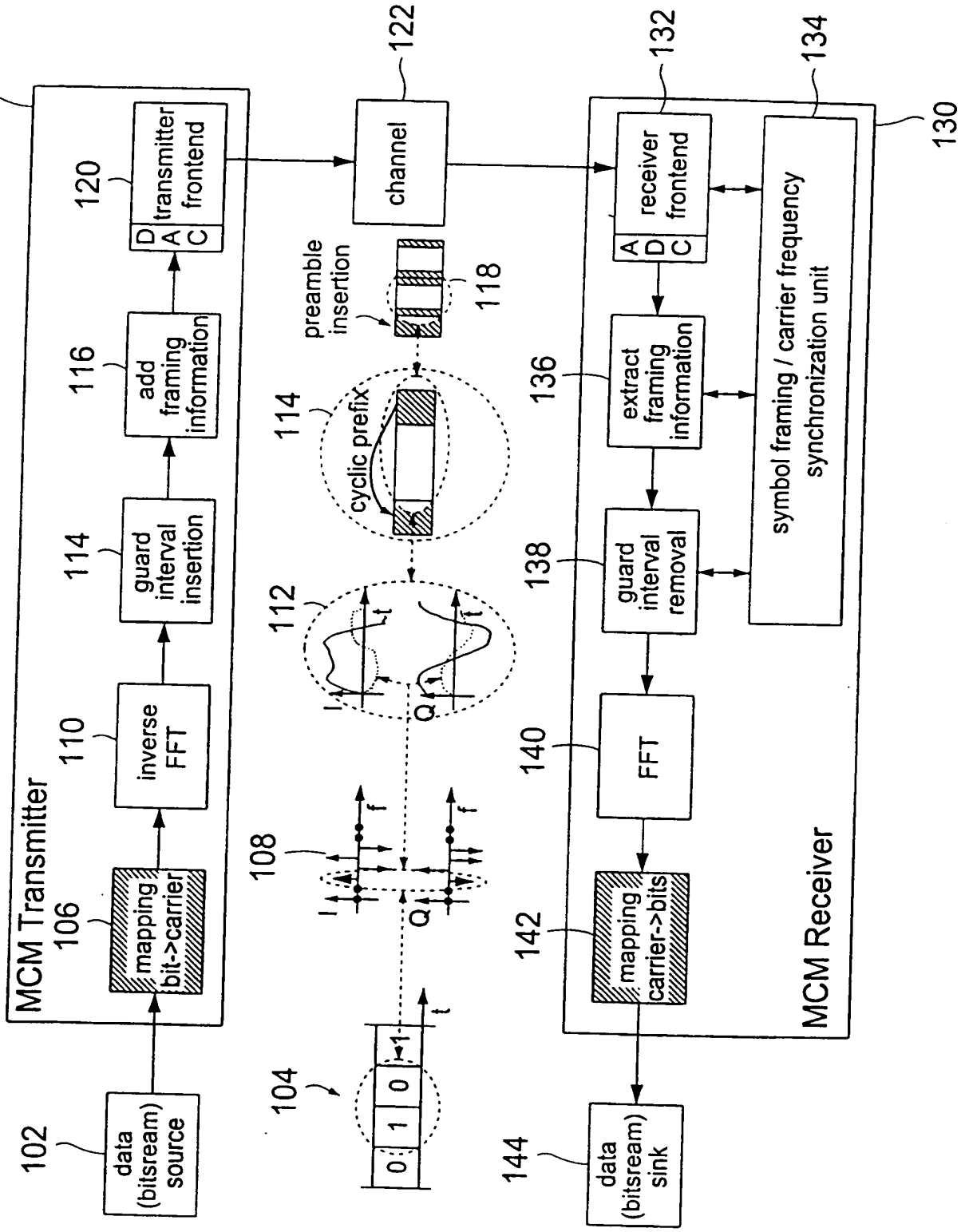
100
MCM Transmitter
102
data (bitsream) source
104
106
mapping bit->carrier
110
inverse FFT
114
guard interval insertion
116
add framing information
120
transmitter frontend
D A C
122
channel
preamble insertion
118
cyclic prefix
114
112
108
I
Q
t
f
0 1 0 1
132
receiver frontend
A D C
134
symbol framing / carrier frequency synchronization unit
130
136
extract framing information
138
guard interval removal
140
FFT
142
mapping carrier->bits
MCM Receiver
144
data (bitsream) sink

FIG.1

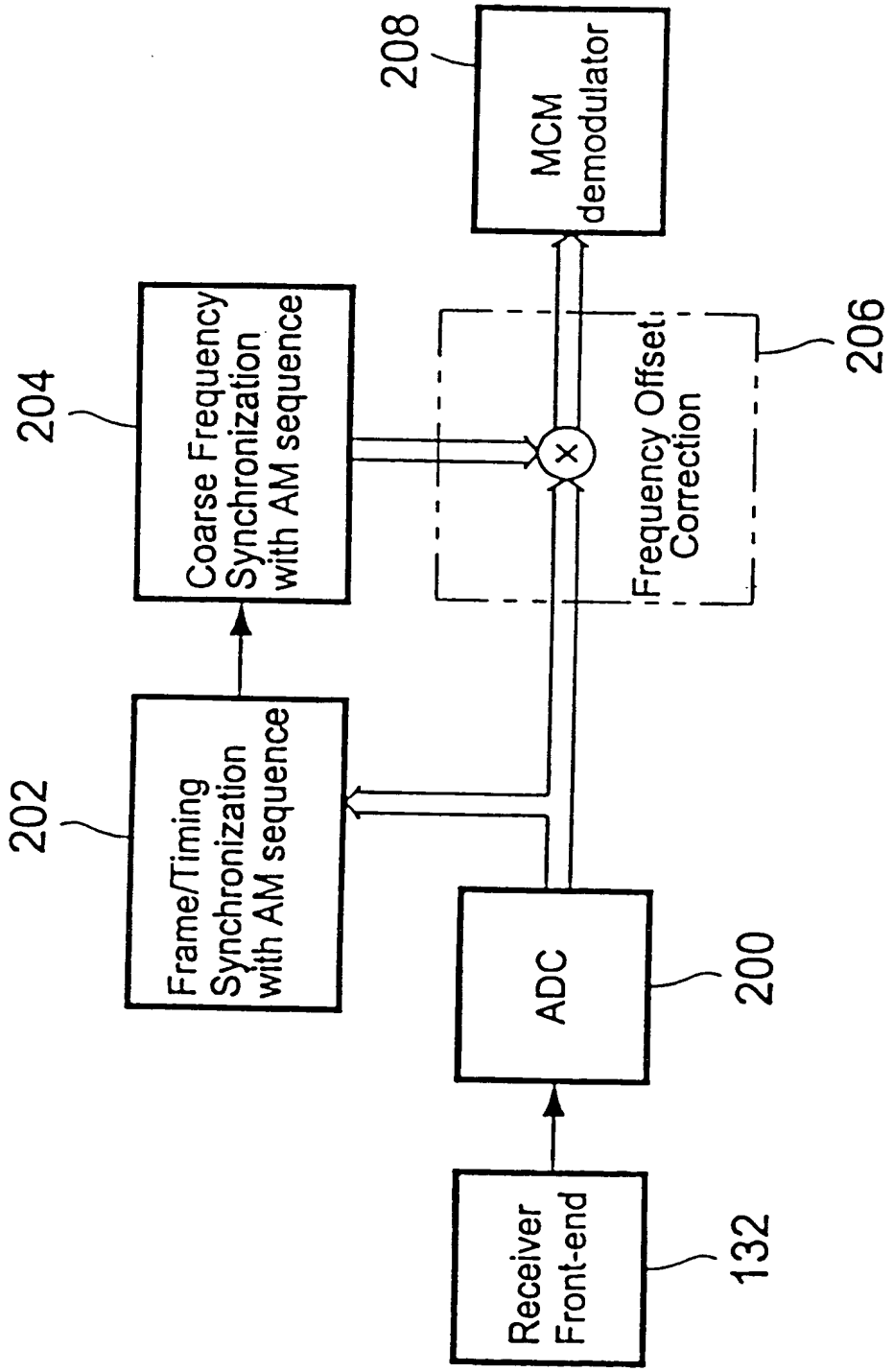
208
MCM demodulator
204
Coarse Frequency Synchronization with AM sequence
206
Frequency Offset Correction
X
202
Frame/Timing Synchronization with AM sequence
ADC
200
Receiver Front-end
132

FIG.2

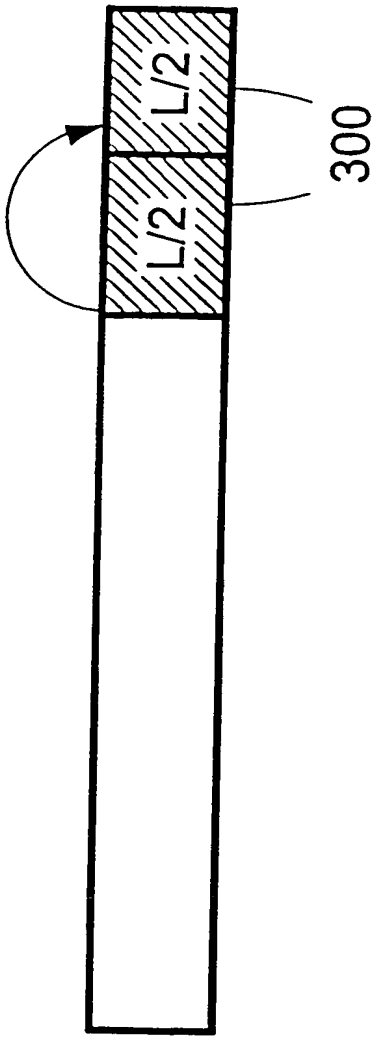

FIG.3

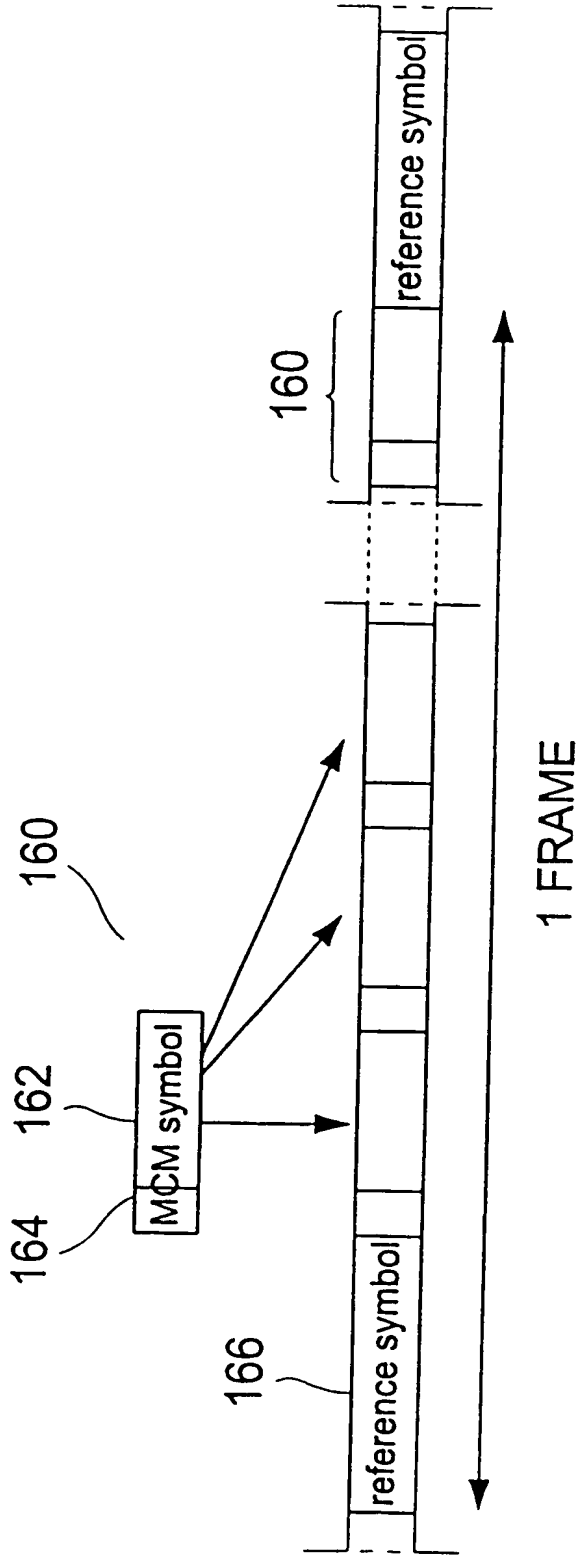
reference symbol
160
1 FRAME
160
162
MCM symbol
164
166
reference symbol

FIG.4

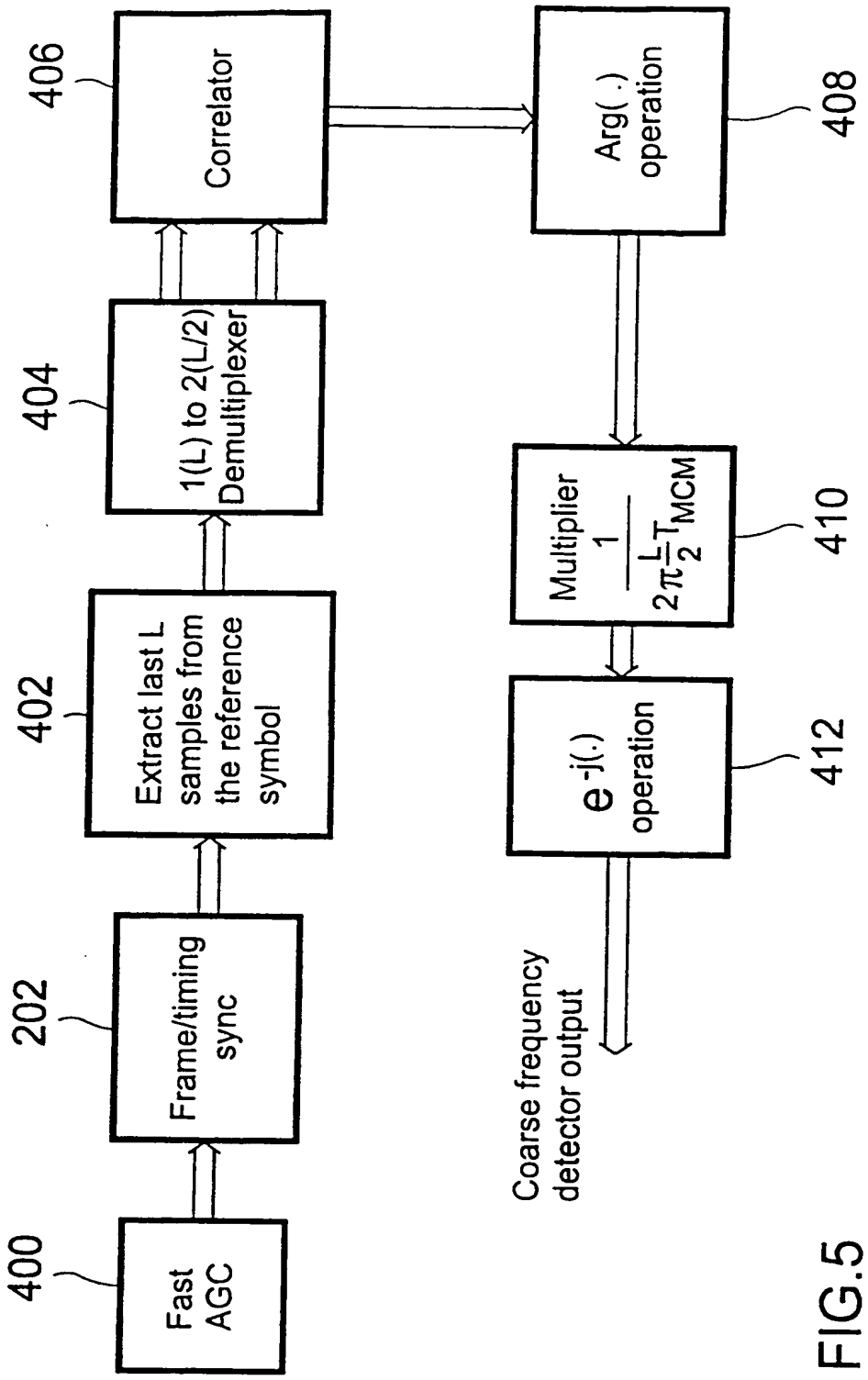
400
Fast AGC
202
Frame/timing sync
402
Extract last L samples from the reference symbol
404
1(L) to 2(L/2) Demultiplexer
406
Correlator
408
Arg(.) operation
410
Multiplier $\frac{1}{2\pi\frac{L}{2}T_{MCM}}$
412
$e^{-j(.)}$ operation
Coarse frequency detector output

FIG.5

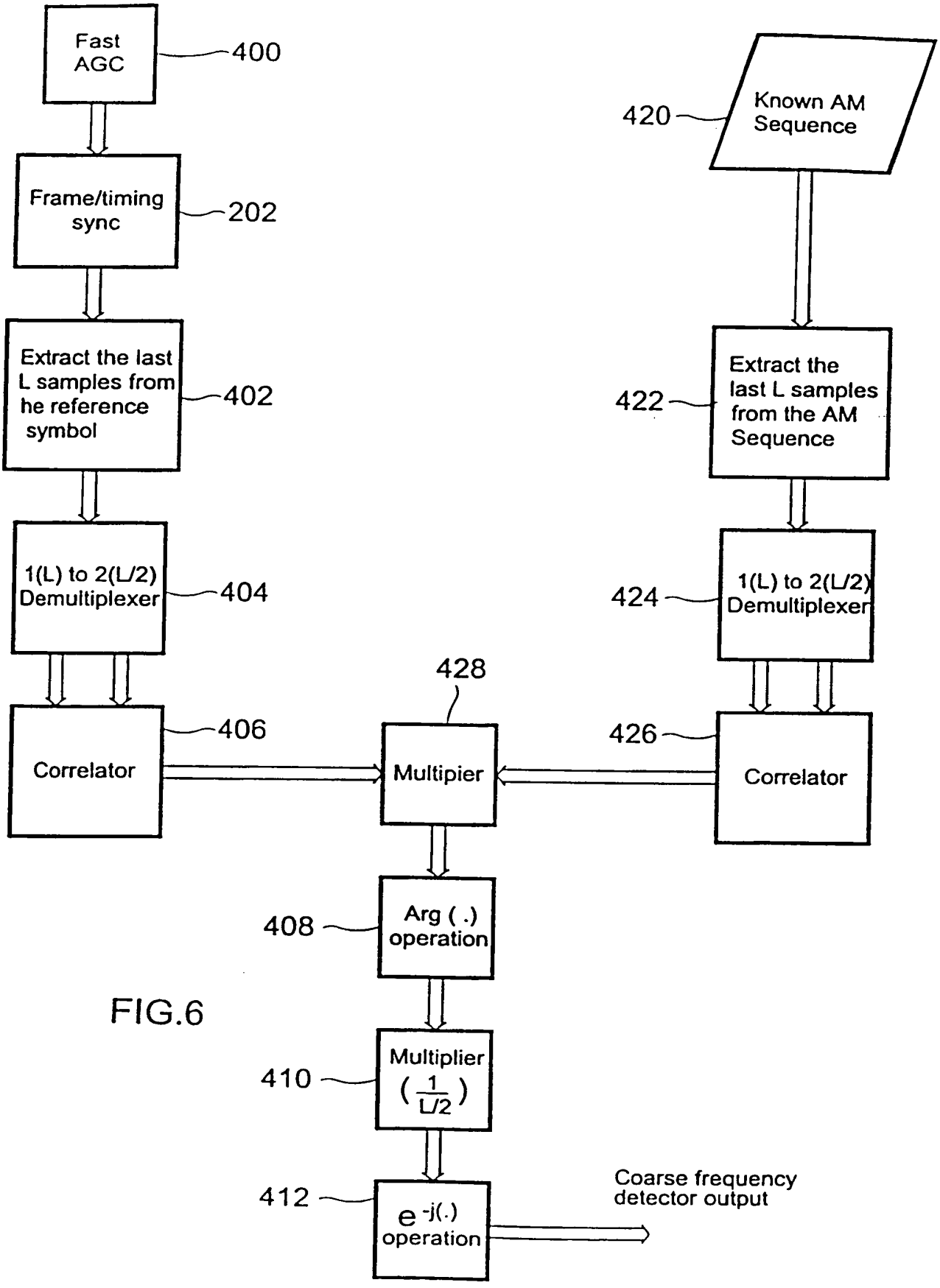
Fast AGC
400
Frame/timing sync
202
Extract the last L samples from he reference symbol
402
1(L) to 2(L/2) Demultiplexer
404
Correlator
406
Known AM Sequence
420
Extract the last L samples from the AM Sequence
422
1(L) to 2(L/2) Demultiplexer
424
Correlator
426
428
Multipier
Arg (.) operation
408
Multiplier (1/L/2)
410
e -j(.) operation
412
Coarse frequency detector output

FIG.6

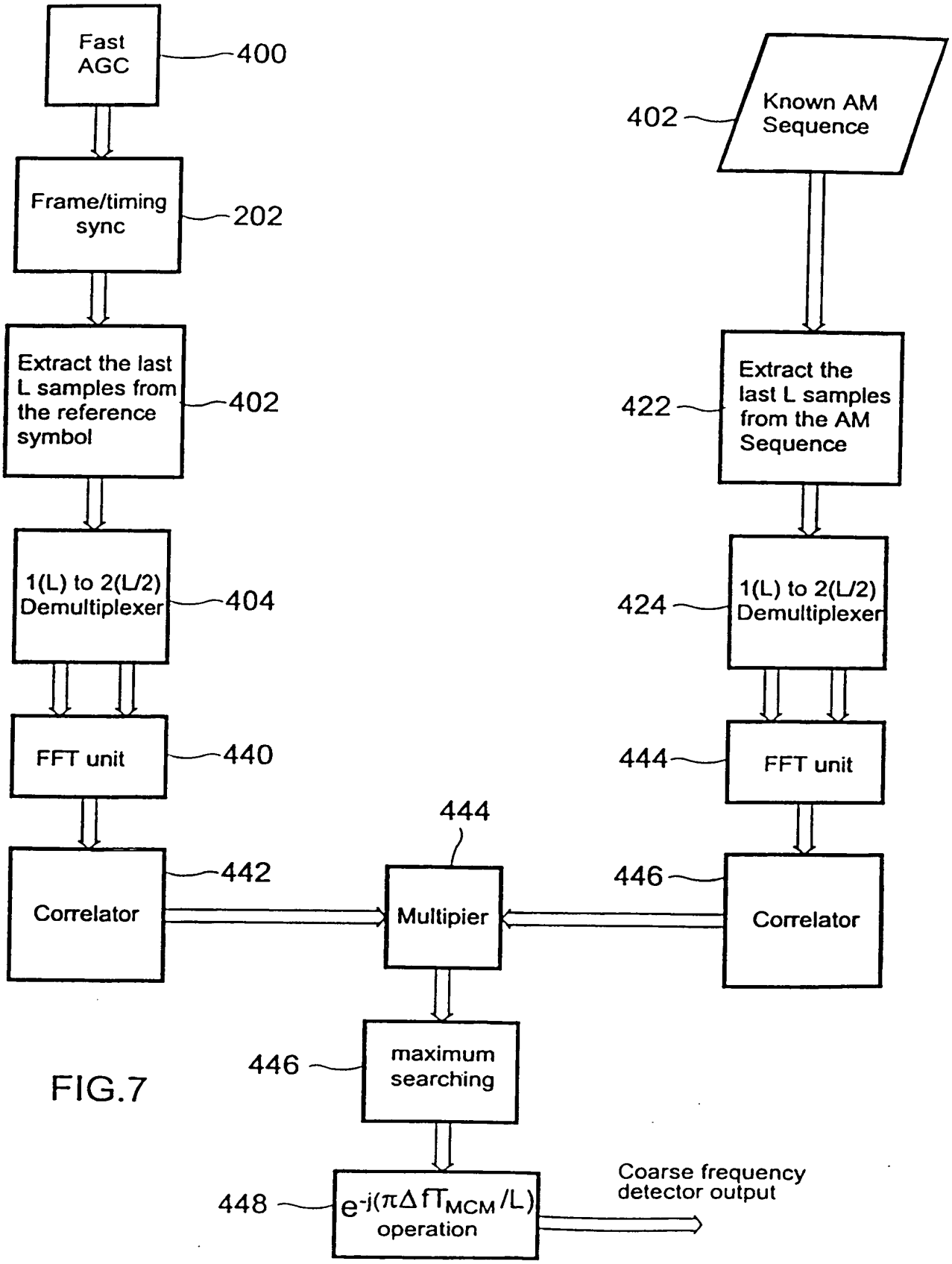
Fast AGC
400
Frame/timing sync
202
Extract the last L samples from the reference symbol
402
1(L) to 2(L/2) Demultiplexer
404
FFT unit
440
Correlator
442
Known AM Sequence
402
Extract the last L samples from the AM Sequence
422
1(L) to 2(L/2) Demultiplexer
424
FFT unit
444
Correlator
446
444
Multipier
maximum searching
446
$e^{-j(\pi\Delta fT_{MCM}/L)}$ operation
448
Coarse frequency detector output

FIG.7

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 98/02170

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04L27/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 98 00946 A (LELAND STANFORD JUNIOR UNIVERSITY) 8 January 1998 see page 17, line 16 - line 22 see page 26, line 17 - page 27, line 2 see page 27, line 14 - line 24 see page 28, line 4 - line 16 --- -/--	1,3,12, 14

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
5 January 1999	12/01/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Scriven, P

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	MOOSE: "A technique for orthogonal frequency division multiplexing frequency offset correction" IEEE TRANSACTIONS ON COMMUNICATIONS., vol. 42, no. 10, October 1994, pages 2908-2914, XP002019915 NEW YORK, US cited in the application see page 2908, right-hand column, paragraph 5 see page 2911, right-hand column, paragraph 5 - page 2912, right-hand column, paragraph 2 ---	1,3,12, 14
A	KELLER; HANZO: "Orthogonal frequency division muliplex synchronisation techniques for wireless local area networks" IEEE INTERNATIONAL SYMPOSIUM ON PERSONAL, INDOOR AND MOBILE RADIO COMMUNICATIONS, 15 October 1996, pages 963-967, XP002063294 New York, US see page 963, right-hand column, paragraph 3 -----	1,3,12, 14

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inte[redacted]al Application No
PCT/EP 98/02170

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9800946 A	08-01-1998	US 5732113 A	24-03-1998

CORRECTED VERSION*

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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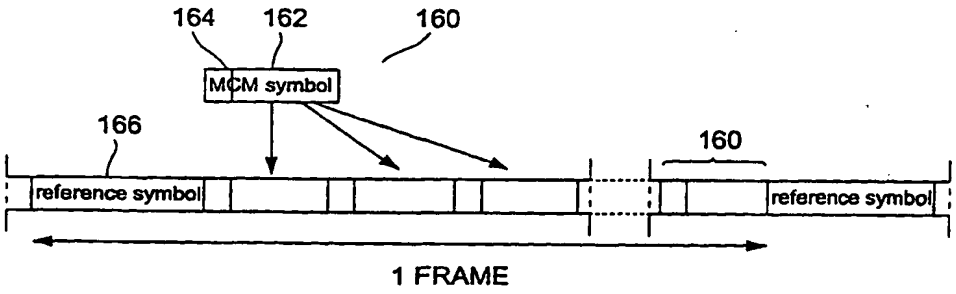
(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: COARSE FREQUENCY SYNCHRONISATION IN MULTICARRIER SYSTEMS



(57) Abstract

For performing a coarse frequency synchronization compensating for a carrier frequency deviation from an oscillator frequency in a demodulation system (130) capable of demodulating a signal having a frame structure, the frame structure comprising at least one useful symbol (162) and a reference symbol (166) which is an amplitude–modulated sequence, firstly the signal is received. Thereafter, the received signal is down–converted. Then, an amplitude–demodulation of the down–converted signal is performed in order to generate an envelope. This envelope is correlated with a predetermined reference pattern in order to determine the carrier frequency deviation. Finally, the oscillator frequency is controlled based on the carrier frequency deviation. The reference symbol may comprise two identical sequences (300). In this case, the envelope obtained by the amplitude–demodulation has two portions which are based on the identical sequences (300). One of the portions of the envelope is correlated with the other one of the portions in order to determine the carrier frequence deviation. The oscillator frequency is controlled based on the determined carrier frequency deviation.

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PATENT COOPERATION TREATY

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INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION**	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
FH980403PCT		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/EP 98/ 02170	14/04/1998	
Applicant		
FRAUNHOFER-GESELLSCHAFT ZUR FÖRDERUNG ... et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. [ ] **Certain claims were found unsearchable** (see Box I).

2. [ ] **Unity of invention is lacking** (see Box II).

3. [ ] The international application contains disclosure of a **nucleotide and/or amino acid sequence listing** and the international search was carried out on the basis of the sequence listing
   - [ ] filed with the international application.
   - [ ] furnished by the applicant separately from the international application,
     - [ ] but not accompanied by a statement to the effect that it did not include matter going beyond the disclosure in the international application as filed.
   - [ ] Transcribed by this Authority

4. With regard to the **title,**
   - [ ] the text is approved as submitted by the applicant
   - [X] the text has been established by this Authority to read as follows:

   FRAME STRUCTURE AND FRAME SYNCHRONISATION FOR MULTICARRIER SYSTEMS

5. With regard to the **abstract,**
   - [X] the text is approved as submitted by the applicant
   - [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this International Search Report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is:

   Figure No. 4
   - [X] as suggested by the applicant.
   - [ ] because the applicant failed to suggest a figure.
   - [ ] because this figure better characterizes the invention.
   - [ ] None of the figures.

INTERNATIONAL SEARCH REPORT

International Application No
EP 98/02170

A. CLASSIFICATION OF SUBJECT MAT
IPC 6 H04L27/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 98 00946 A (LELAND STANFORD JUNIOR UNIVERSITY) 8 January 1998 see page 17, line 16 - line 22 see page 26, line 17 - page 27, line 2 see page 27, line 14 - line 24 see page 28, line 4 - line 16 --- -/--	1,3,12, 14 (23, 25, 34, 36)

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
5 January 1999	12/01/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Scriven, P

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INTERNATIONAL SEARCH REPORT

International Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
EP 98/02170

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9800946 A	08-01-1998	US 5732113 A	24-03-1998